JOURNAL OF

Metals

TECHNOLOGY · PRACTICE

APRIL 1949
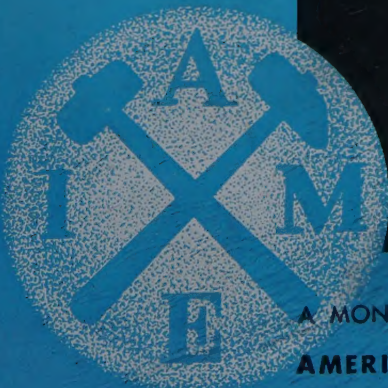
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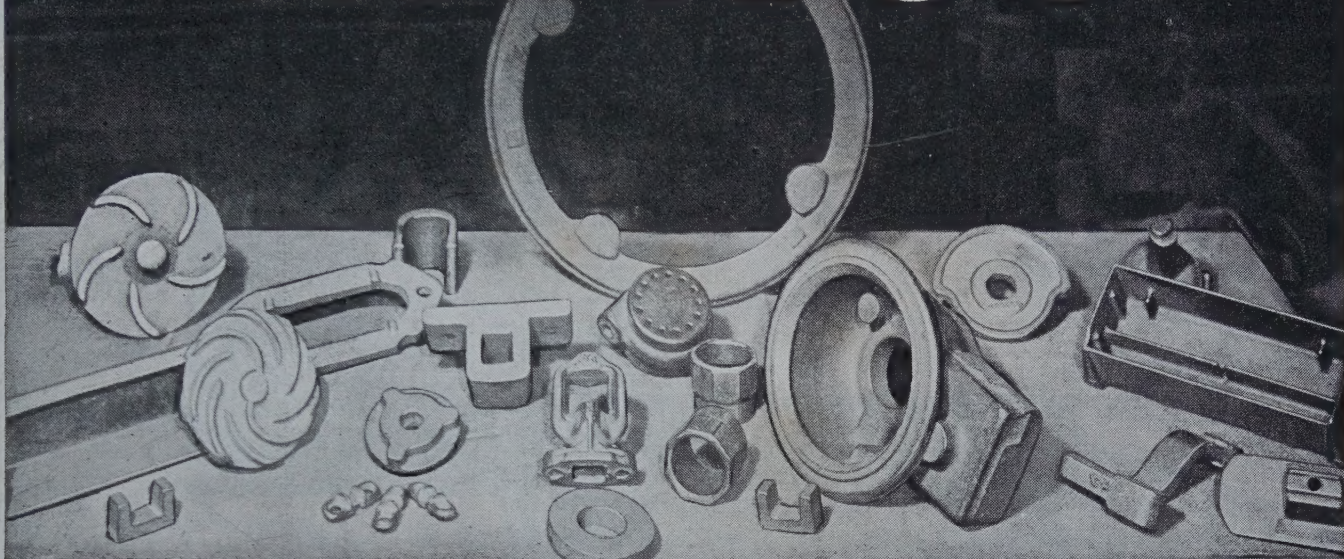
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COVER PHOTOGRAPH—A fractograph of ingot iron, taken by C. O. Worden in the research laboratory of C. A. Zapffe, Baltimore. It has been annealed, embrittled with hydrogen by pickling in H_2SO_4, and fractured at the temperature of liquid nitrogen. The whole field is a single grain, the facet boundary being the grain boundary. (475X.)

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS, INC.
Metals Branch—AIME also publishes *Mining Engineering* and *Journal of Petroleum Technology*.
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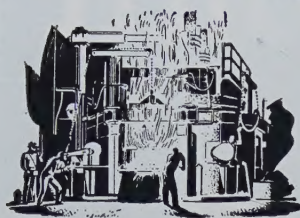
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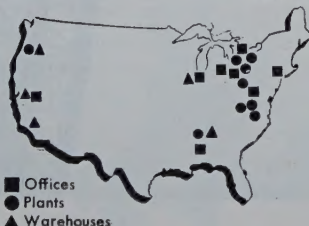
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GUEST EDITORIAL

GEORGE S. ROSE • SECRETARY, AMERICAN IRON AND STEEL INSTITUTE

PERFORMANCE OF THE U. S. STEEL INDUSTRY

Misgivings expressed by critics of the steel industry have been answered, to a large extent, by the performance of the industry. Its furnaces have been pouring the greatest output of steel the world has ever known. Its capacity, at more than 96,000,000 tons of raw steel a year, is now greater than ever, and further large expansion is planned during the next two years. The steel companies' outlay for expansion and improvement this year alone will reach $627,000,000, an unprecedented high.

Its high output underlies the fact that factories have built up a sizable flow in the pipeline of peacetime production within a remarkably short time after years of war production. If strikes had not caused the direct loss of more than 20,000,000 tons of raw steel since war's end, in addition to losses caused by insufficient quantity and poor quality of certain raw materials, the transition from sellers' to buyers' markets would have occurred sooner in numerous lines of products.

Last year, the steel industry came within a few days' production of its record annual output of the war. Then, in January, 1949, production exceeded 8,000,000 tons for the first time in history. That amount in a single month is more than the entire 1948 output of any country except Britain and Russia. And, in February, the production pace was accelerated again at a higher daily rate.

By pushing their programs of expansion and improvement, steel companies increased total annual ingot capacity by over 1,800,000 tons last year to 96,120,930 tons, an amount substantially higher than expected under plans reported a year ago. By the end of 1950, capacity will probably be almost 99,000,000 tons.

Furnaces, operating fully, can now pour more than three tons of raw steel every second for a full year. Such high production calls for larger quantities of raw materials than have ever been assembled by the industry. Nearly 250 tons of iron ore will be required each minute as well as 200 tons of coal and large quantities of other materials, some from distant parts of the world.

To transport a year's ore, coal and limestone would require nearly 5,500,000 freight cars, loaded to 50 tons each, for one trip each.

The metallics to produce 96,120,930 tons of steel per year must come mainly from two sources: Iron made in blast furnaces and steel scrap. About 130,000,000 net tons of iron ore will be required per year. While ore men keep the material coming out of the mines and moving according to schedule, night and day, they will be thinking about the future iron ore supply, the exploration and development of foreign reserves and beneficiation of low grade ores.

More than 50,000,000 tons of scrap will be required a year, a large part of it yielded by the mills in their own operations. That tonnage will include a minimum of about 18,000,000 tons of purchased scrap, assuming the industry gets the benefit of full operations at blast furnaces. In 1948, however, about 25,000,000 tons of purchased scrap were used by the iron and steel industry.

About 35,000,000 tons of limestone will be needed; 111,500,000 tons of coal; 1,546,000 tons of manganese ore; 634,000 tons of chrome ore; and 144,000 tons of metallic nickel.

It is important to recognize that we are dealing with exhaustible resources. Every ton of metal extracted, refined and put to use is a subtraction from the aggregate which this earth offers. Some metals, once used, can be recovered from scrap, and in secondary form contribute substantially and repeatedly to the needs of industry, but existing resources cannot be increased by any magic of metallurgists.

In expanding and improving their facilities to make more steel, companies of the industry have already spent $1,407,000,000 since the war ended and will lay out an additional $627,000,000 this year, bringing the total of postwar expenditures to over two billion dollars. Companies of the industry overshot their announced programs of expansion and improvement in 1948, both in tons and dollars, and their aims as announced at the start of this year have been understated, rather than exaggerated. The general accuracy of capacity statements in recent years has been subsequently confirmed by production reports, which in themselves were on the low side because they did not include tonnages produced by some companies temporarily attracted to the making of steel ingots for resale.

All these facts indicate that the steel industry has shown a sense of responsibility toward the current welfare and future strength of this country.

The fate of the steel industry is the future of this country. Profitable, progressive, strong in steel, this country will remain powerful in economic and political influence. Steel cannot be profitable, progressive and strong if beset by governmental theorizers, hostile policies, unreasonable pressures and insidious propaganda.
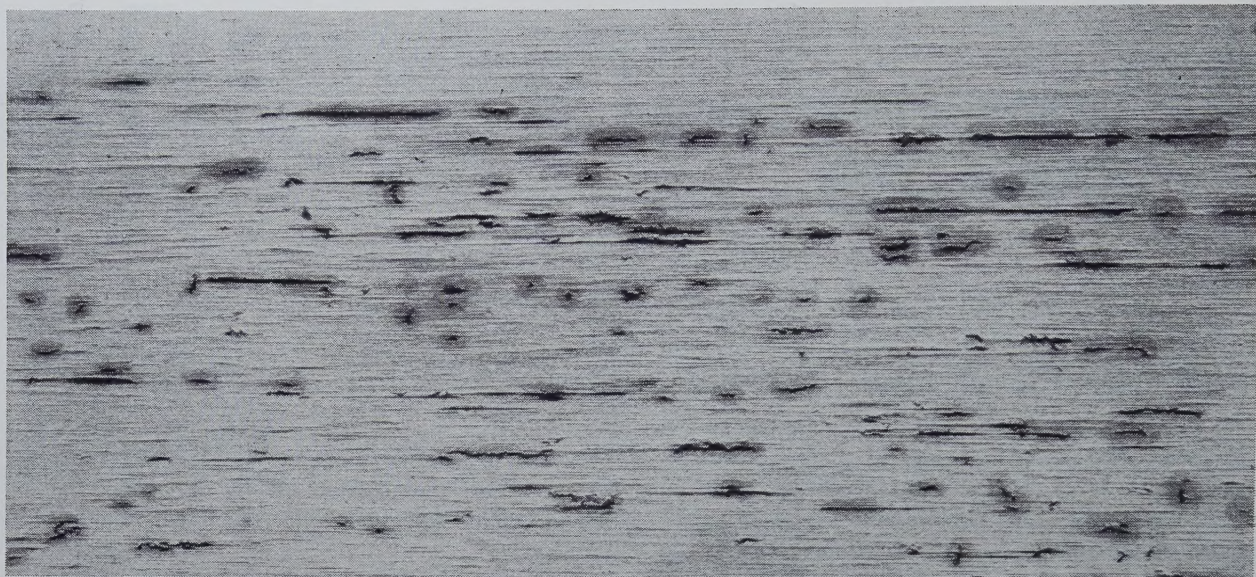
Etched cross section of 90 lb. rail, showing shatter cracks caused by hydrogen (¾ x)

(Courtesy, Carl A. Zapffe)

Nitrogen and Hydrogen in Metals

An Up-To-Date Review of Some Known Facts

ONE of the most interesting phenomena of modern metallurgy is the scarcity of quantitative data on the effect of nitrogen and hydrogen on the properties and overall quality of commercial metals, especially steel. One wonders why such data are so scarce; certainly the metallurgist has always known that there is ample opportunity for molten and solid metal to take up gas, because practically all metals are melted, refined, and fabricated in air containing nearly 80 per cent nitrogen; and, since water—in the air, or formed by the combustion of fuel, or held mechanically or chemically in the raw materials—is almost always present, the opportunity for the metal to absorb hydrogen is broad.

Furthermore, the metallurgist has had ample experience to watch the operating man take care of the gas content of his metal so that it would not cause trouble. The baking of pickled steel rods to get rid of absorbed hydrogen so that they can be drawn into wire is only one of the many common examples in which the problem of gas in metal was recognized years ago and solved satisfactorily in the mill.

Several explanations for this lack of quantitative data on the presence of gases in metals and on their effect on the properties are apparent. One that has been advanced is that metallurgists are prudent as well as inquiring individuals where their art and science is concerned. Prudent means wisely cautious in practical matters and the prudent man should, therefore, be as cognizant of facts to be shunned as he is of facts to be sought. The most reasonable explanation, however, is that our ignorance in this field is due to the difficulty of securing representative samples and analyzing correctly and easily

for the small amounts (by weight but not by volume) of the gases that are present.

There is no dearth of qualitative knowledge on gases in metals, and this includes steel; in fact, Henry Marion Howe, writing in 1889 devoted many pages and cited nearly 100 references in discussing the presence of nitrogen and hydrogen in steel, and a large amount of work has been done in laboratories all over the world since Howe prepared his summary 60 years ago. For example, Sieverts (and associates), who worked out the temperature—pressure—solubility relationship now known as Sieverts' law, published approximately 50 papers in Germany between 1907 and 1943, and D. P. Smith, author of a recent (1948) monograph on hydrogen in metals gives a bibliography of 1467 references to this gas alone. Smithells wrote a book on gases in metals 10 years ago and two Institute of Metals Division lectures have been devoted to the subject. Despite this, however, we know relatively little about the effect of gas on the properties and overall quality except for the readily observable fact that in general the solubility of gas in a metal decreases with temperature and that this decrease is pronounced, during solidification, a phenomenon that is responsible for blow holes, blisters, fissures, and other manifestations of porosity in the solid metal.

solubility of nitrogen and hydrogen in metals

There has been considerably more quantitative work done on the solubility of nitrogen and hydrogen in non-ferrous metals and alloys than on their solubility in carbon and alloy steels, and a majority of Sieverts' papers
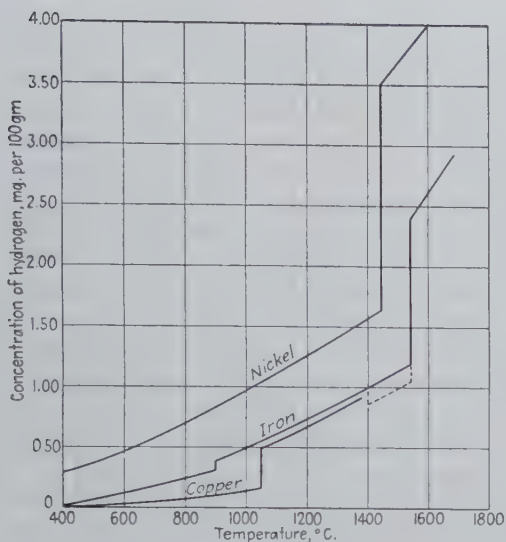
Fig. 1—Effect of Temperature on the solubility of hydrogen in nickel, iron and copper at one atmosphere.

gave data on gases in metals other than iron. These two gases are distinctly—and often readily—soluble in nearly all of the metals except those of the so-called white metal class (tin, lead, zinc, antimony, and their alloys); at atmospheric pressure solubility increases slowly with temperature; there is then a rapid increase at the melting point, and above this temperature the solubility increases slowly again. This is shown by Fig. 1 which contains values for nickel, iron, and copper replotted from data collected by D. P. Smith.

A good review of the few fundamentals that we are certain of, in connection with the solubility of nitrogen and hydrogen in iron (and steel), and including a discussion of Sieverts' law, was given by Carney, Chipman, and Grant, as an introduction to the metallurgy session at the 1948 Electric Furnace Steel Conference.

Sieverts' law, which states that at all temperatures the solubility of nitrogen or hydrogen in a metal is proportional to the square root of the pressure, is important. It the first place it tells us that a gas must dissociate with the atomic state to be readily absorbed by the metal. In the second place it enables us to estimate the solubility of mixtures of gases as well as the solubility of the individual gas. For example, at 2900 F and at atmospheric pressure, 30 cu. cm. of a gas containing 100 per cent hydrogen, or 33 cu. cm. of a gas containing 100 per cent nitrogen will dissolve in 100 gm. of metal; but under the same conditions 45 cu. cm. of a gas containing 50 per cent each of hydrogen and nitrogen will dissolve. We do, of course, never approach equilibrium in the case of the solubility of a pure gas but with gas mixtures such an approach is entirely possible.

Of even more interest is the effect of temperature on the solubility of gas in steel. This is shown in Fig. 2. Nitrogen and hydrogen are more soluble in austenite than they are in alpha or delta ferrite, and with both gases the solubility increases rapidly at the melting point. This has important consequences for steel quality, both as regards freedom from porosity—which as Fig. 2 shows is not as prevalent in austenitic steels as in those grades

in which austenite is not normally present at room temperature—and, in the case of hydrogen, in the presence or absence of flakes or hairline cracks, these are almost never found in austenitic steels.

Figure 2 is applicable, but only as indicating general trends, to unalloyed steels and, unfortunately, little is known about the effect of the commonly used alloying elements that may be present in pearlitic steels. It has been found that the solubility of nitrogen in ferro-chromium and ferrovanadium increases rapidly with increasing percentages of the alloying metal, and Darken stated at the Electric Furnace Steel Conference that the solubility of nitrogen in ferromanganese is ten times its solubility in iron, but there is no certainty that high nitrogen even if present in the ferroalloys used will be present in the steel as it is probably flushed out of the bath, at least partly, by carbon monoxide during refining. On the other hand, nitrogen may be picked up from the air during tapping the heat and teeming the ingots.

There are a few elements, notably aluminum, titanium, and zirconium that form stable nitrides (inclusions) and thus remove or "fix" the nitrogen that is in solution in steel, but no element acts similarly with hydrogen. The only method of insuring that steel, and other metals for that matter, will not contain too much hydrogen is to prevent them from coming into contact with a source of this gas.

some known facts re nitrogen in steel

There is probably more quantitative data available on nitrogen in steel and on its effect on overall quality than there is on hydrogen. This is due largely to the development of nitriding as a practical process of surface hardening, and to the experimental work that has been carried on over the past 10 years or more in the research labora-
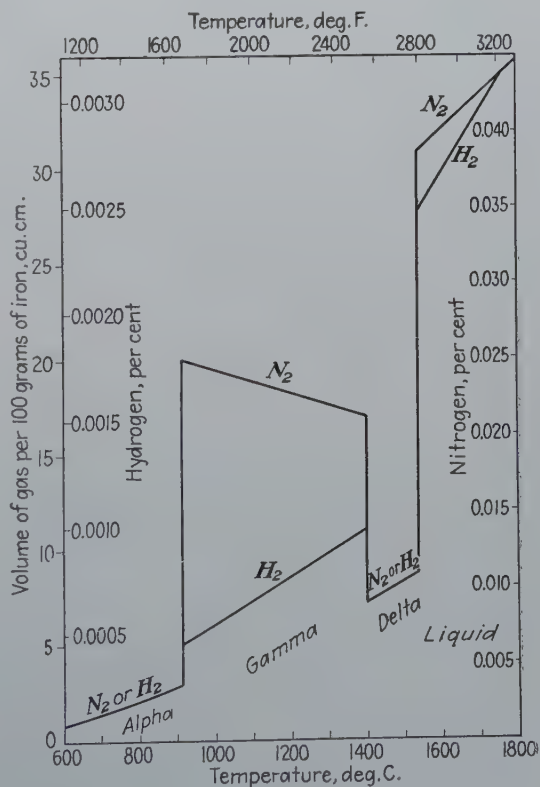
Fig. 2—Solubility by Volume of Nitrogen and Hydrogen in Iron at Various Temperatures

tories of a number of the larger steel companies. A strong impetus to such work was supplied by a paper by H. W. Graham presented in 1932 to the American Iron and Steel Institute in which he suggested that such vague and esoteric terms as "body" or "timbre," which had crept into metallurgical terminology to explain differences in properties frequently encountered in steels of similar composition and treatment, could be eliminated if quantitative data were secured on the effect of nitrogen and other gases; and that such unpleasant phenomena as strain-aging embrittlement, and the difference in response of various heats of a single grade, or even various ingots of a single heat to cold working—known as strain sensitivity—could be explained by differences in nitrogen content.

Graham's suggestions have been followed and a considerable amount of experimental data is now available (summarized lately by Comstock, Urban, and Cohen, and by Case and VanHorn) that shows clearly that nitrogen is largely responsible for strain sensitivity and strain-aging embrittlement. The data indicate that these phenomena occur when nitrogen is present in steel primarily as iron nitride, and that the higher the nitrogen, the greater is the embrittlement evident after cold working.

Steels of the same chemical analysis but differing in strain sensitivity usually have about the same tensile properties if cold worked alike. Their toughness, however, as determined by the single-blow impact test varies widely: for example a 0.20 per cent carbon steel, cold drawn about 10 per cent, will have an Izod value in the neighborhood of 60 ft. lb. if not strain sensitive, but if it is sensitive the Izod value will be of the order of 10 ft. lb.

To eliminate, or at least greatly reduce, strain sensitivity a sufficient quantity of a strong deoxidizer—for example aluminum or titanium—must be added, so that after deoxidation is complete there will be an excess to react with the iron nitride to form aluminum—or titanium nitride and thus fix the nitrogen as relatively innocuous nitride inclusions. This practice has become relatively wide-spread among American steel producers with the result that the automotive and other industries who make extensive use of cold forming can now rely on an ample supply of low-carbon deep-drawing steel in which the tendency for age hardening at room temperature is so slight that it can be neglected.

some known facts re hydrogen in metals

There is probably no element in the periodic table that can move in and out of steel and many other metals as readily as hydrogen, especially when it is available in atomic form. And it is usually readily available, from the presence of water vapor, and from the release of nascent hydrogen during such chemical processes as pickling and electrolysis. In addition to being responsible (together with nitrogen and carbon monoxide) for blow-holes, it may be responsible for brittleness in otherwise tough and ductile metallic materials and, unlike the garden variety of brittleness in metals and alloys, it is not accompanied by an increase in hardness and strength. Fortunately, however, when the source of supply for the hydrogen is removed the gas readily diffuses out;

slowly at room temperature and more rapidly as the temperature is raised. The extreme brittleness in freshly pickled steel rods can be completely eliminated by baking the rods for a short time in an oven maintained at approximately 500 F. In the same category, high-carbon steel springs which are to be galvanized or cadmium plated to improve corrosion resistance absorb hydrogen during the electrolytic cleaning and plating process; the accompanying brittleness can be eliminated by heating the plated springs at about 400F which drives off most of the occluded hydrogen.

In many cases, however, the hydrogen is not so readily taken care of. If the presence of hydrogen is not suspected or if it has segregated (which happens readily) slow cooling from a high temperature may cause the hydrogen to collect in submicroscopic fissures in the metal with the result that high pressures may build up. The triaxial stresses set up in the metal to balance the gas pressure prevent normal plastic flow and the steel is embrittled.

The role of hydrogen in the formation of flakes and shorter cracks is well known. Most of these defects are due to a combination of hydrogen and internal stresses which results from phase transformations and/or rapid cooling. Thus, the most common preventative of flake is slow cooling after hot working; this prevents high internal stresses from building up and permits the occluded hydrogen to diffuse out of the metal.

In this connection a discussion presented by Derge of the paper by Carney and his co-workers at the Electric Furnace Steel Conference is of interest. Derge emphasized a fact, commonly neglected: namely, that the steel maker may (and usually is) blamed for hydrogen that is introduced during one or more of the processes by which the ingot is worked into final shape. One of the end products of the combustion of any fuel is steam and this may react with iron ($Fe + 2H_2O = 2H + FeO$) to form atomic hydrogen. According to Derge there is considerable evidence that when steel is heated in a gas-fired furnace, hydrogen is absorbed; in fact scaling is evidence that the reaction is going on, and if the steel is initially low in hydrogen the reaction proceeds from left to right, and hydrogen diffuses into the body of the metal.

In steel melting the critical period for absorption of hydrogen is during deoxidation, and practically all of the experts in this field emphasize that slag-making materials added to the bath during this period should contain no moisture. Further proof along this line was presented at the Electric Furnace Steel Conference by Pierce, and by Powell, Harris, and Morris. The former warned that moisture in the raw materials or high humidity in the air would raise the hydrogen content of the bath during the deoxidation period. If oxygen is used in the bath, however, the amount of hydrogen (and the tendency of the steel to flake) is greatly reduced, and Pierce cited results of two years' practice with and without oxygen which indicated that during one year when oxygen was used on all heats, rejections on account of flake were only one-tenth of the rejections during a similar period when oxygen was not employed.

Powell and his associates attempted to correlate the relative humidity in the air with the bleeding of stainless steel ingots, a hydrogen-induced defect. In the summer months when the air was naturally moist the amount of

bleeding increased greatly. The authors uncovered the interesting fact that 100 lb. of lime that had been exposed to air with a relative humidity of 85 per cent for two days contained 32 lb. of water. If such lime is used for the deoxidizing slag in the basic electric furnace it is evident that considerable hydrogen may be absorbed.

effect of hydrogen on structure and properties of steel

Sims, Moore and Williams in a recent paper (T.P. 2454 Met. Tech. 1948) summarized the relation of hydrogen to the structure of steel as follows: "The hydrogen contained within a section of steel is normally in three portions: first, that in true solution in the lattice; second, a portion in excess of that which can be in true solution and which has precipitated and diffused into blowholes and other major openings; and third, a portion which has been rapidly precipitated and has been unable to diffuse far from the point of precipitation." None of these portions has any marked effect on the metallographic structure and only the third portion has an effect on the properties.

Hydrogen may have a marked effect on the isothermal transformation diagram of carbon or low alloy steels. This was shown recently by two papers by J. H. Andrew and several associates (J. British Iron and Steel Inst. v. 153, 1946, and v. 156, 1947). This work is important as it shows definitely that in the pearlite range hydrogen slows down the transformation of austenite, thus increasing the hardenability. In a 0.20 per cent carbon, 3 per cent chromium steel hydrogen (6 to 8 cu. cm. per 100 gm. of steel) increased the time for the austenite pearlite reaction to start from 10 to 15 min.

Quantitative data on the effect of hydrogen on mechanical properties, especially ductility, were given at the Electric Furnace Steel Conference by Marshall, Garvey and Llewelyn, and in a recent T.P. 2454 by Sims, Moore, and Williams. As it is well known that hydrogen will diffuse slowly out of steel at room temperature, and much more rapidly at higher temperatures Marshall Garvey, and Llewelyn determined the effect of hydrogen on the properties of a heat of semikilled 1025 steel treated in various ways to affect hydrogen diffusion. The material was rolled to 1½ in. rounds, from which tensile specimens were cut immediately and after holding at room temperature for periods up to a month. The same procedure was followed for sections of specimens aged at 350F for one to eight hr.

Aging at room temperature or at 350F resulted in a marked increase in ductility especially in reduction of area values. Some selected results for as-rolled bars are collected in Table 1. As would be expected the increase in

Table 1
Relation Between Aging Time and Ductility of Semikilled 1025 Steel Rolled to 1½ in. Rounds

Aged At Room Temperature			Aged at 350 F		
Aging Time, Days	Elongation In 6 in., Per Cent	Reduction of Area, Per Cent	Aging Time, Hours	Elongation In 6 in., Per Cent	Reduction of Area, Per Cent
0	34	47	0	34	47
2	37	53	1	34	52
6	36	53	2	35	53
10	38	56	3	35	54
14	38	56	4	36	56
21	38	58	6	35	59
28	42	59	8	38	58

ductility with aging time is more rapid for an aging temperature of 350F than when the specimens are not heated above room temperature. Marshall and his associates also found no appreciable difference in the aging behavior in rolled bars which were machined just before testing and bars that were machined and then aged indicating that the increase in ductility was due to the hydrogen and not to the relief of stresses by machining. Analogous results were obtained on a heat of 1025 killed with silicon and aluminum.

Further tests were made on specimens machined from 5 x 5 in. billets of a 1010 steel that contained an unusually high hydrogen content. The specimens were treated to eliminate variable amounts of hydrogen and the reduction of area was determined. As the hydrogen decreased from 0.00057 per cent to 0.00014 per cent the reduction of area increased from 13 to 64 per cent. A plot of the relation between hydrogen and reduction of area is given in Fig. 3. Additional confirmation of the effect of hydrogen on ductility was secured by Charpy impact tests at subnormal temperatures. Impact resistance was determined on specimens of 1010 steel containing 0.00046 per cent hydrogen and on specimens of the same lot of steel treated (6 hr. at 350F in vacuum)
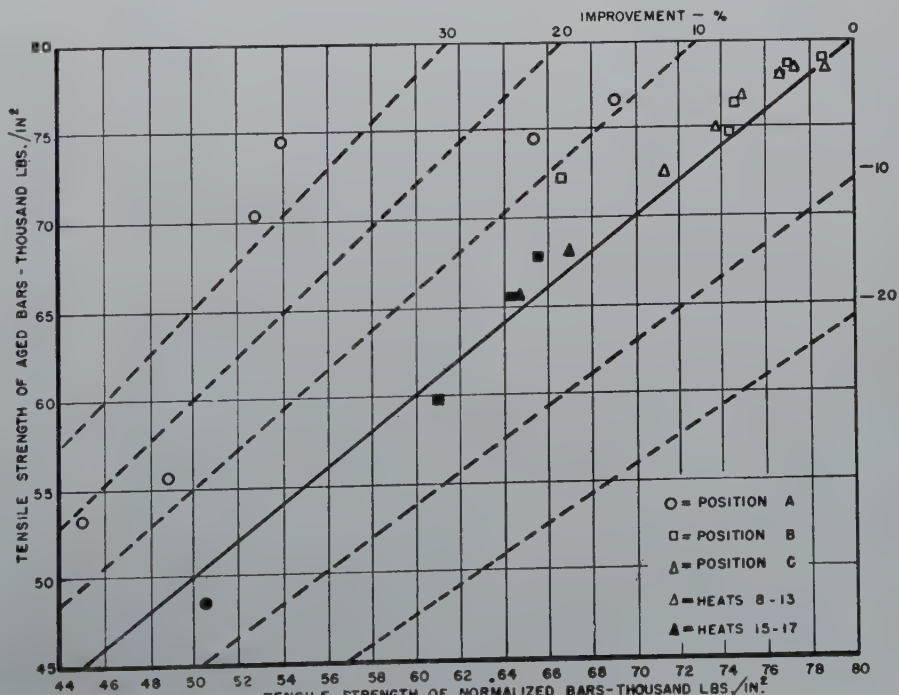
Fig. 3—Effect of Aging on Tensile Strength
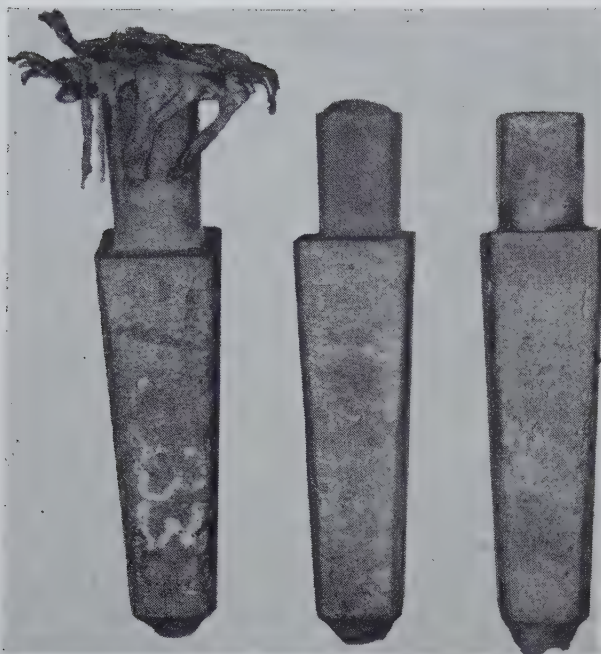
Three degrees of gas activity shown in the risers of 120 lb. steel ingots. Left, severe "bleeding" or "backing up in the mold." Center, slight gassiness. Right, piped riser of sound ingot. The gas causing this activity is principally CO in unkilled steels, H_2 in killed steels and cast irons and N_2 in certain unusual cases of high nitrogen content.

so that the hydrogen was lowered to 0.000091 per cent. The transition temperature for the low hydrogen specimens was 10 to 20F below the transition temperature for specimens containing 0.00046 per cent hydrogen. Both

series of specimens, however, were brittle at temperatures of 10F or below.

Sims, Moore and Williams reported a large number of values for the ductility of cast steels as affected by the hydrogen content. In amounts of 0.10 to 0.40 R.V. (1 relative volume [R.V.] = 12.7 cu. cm. per 100 gm. of metal) will lower the ductility as measured by elongation and reduction of area to 15 to 30 per cent of the value usually characteristic of comparatively hydrogen-free steels. In general the exact percentage of hydrogen necessary to cause this damage varies widely depending on such factors as the number and size of the sites where the hydrogen has precipitated and on the amount of hydrogen segregation. The effect of hydrogen is the least pernicious when it is more-or-less evenly distributed over many sites, and it is the greatest when it is segregated in a few locations, any of which may be the site of brittle failure.

Authorities consulted:

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H. W. Graham, Yearbook, American Iron and Steel Inst., 1932;

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S. L. Case and *K. R. VanHorn*, The Alloys of Iron and Aluminum, Alloys of Iron Monograph;

In Preparation: Papers and transcript of discussion, Electric Furnace Steel Conference, Pittsburgh, Dec. 1948, *C. E. Sims*, *G. A. Moore*, and *D. W. Williams*, Met. Tech. AIME, T.P. 2454, Oct. 1948.

1950 TRANSACTIONS VOLUMES

Metals Branch Volume to be Number 185

Many compliments have been received to the effect that reference can now be made to a page number as well as to the date of issue when referring to technical papers published in the monthly journal of the Metals Branch of the AIME. This page number will be the same as will appear in the final bound volume of the AIME Transactions.

It has been called to our attention, however, that those planning to make a permanent reference to a paper would like to refer to it by AIME Transactions volume number rather than temporarily referring to it by giving the name and date of the journal in which it appears, thus: JOURNAL OF METALS Technology Practice, March, 1949, page 228 Metals Transactions Section. The above reference, of course, will locate the paper and is the only form in which the paper will be available dur-

ing 1949. However, for permanent reference the above paper may be referred to more simply by saying: AIME Transactions Volume 185, page 228. The volume number of the 1950 AIME Transactions Volume of the Metals Branch will be 185. It will include all papers published in the JOURNAL OF METALS, Transactions Section during the calendar year 1949.

Starting with the May issue, each page of the Transactions Section of the JOURNAL OF METALS will carry the volume number as well as the page number. This should clarify and simplify permanent references and members may note on earlier issues that the Metals Transactions Section is part of Volume 185. Although the bound volume 185 will not be issued until 1950, the reference by volume number to technical publications appearing currently in the JOURNAL OF METALS is adequate.

Also, for your information all dis-

cussion of the 1948 fall meeting papers of the Institute of Metals Division will appear in the May, 1949, issue of the JOURNAL OF METALS. It will appear in the 1950 Transactions carrying the same page numbers as it does in the May JOURNAL OF METALS, a title page appearing with the May journal will refer to the date of issue in Metals Technology in which each of these papers presented at the fall meeting appeared. All fall meeting papers of the Institute of Metals Division plus all 1949 Annual Meeting papers of the Institute of Metals Division which were issued in 1948 will appear without discussion in Volume 180 of the AIME Transactions, Institute of Metals Division, for 1949. Discussion of the Annual Meeting papers, some of which appeared in 1948 and some of which appeared in 1949, will appear in a subsequent issue of the JOURNAL OF METALS for 1949 and accordingly in the 1950 Metals Branch AIME Transactions Volume 185.

New England IMD Will Meet at Springfield, Mass.

Seven technical papers, a trip through two plants in the metal-working field and a formal dinner will feature the third annual meeting of the New England Regional Conference, Institute of Metals Div., AIME, at the Sheraton Hotel, Springfield, Mass. Friday and Saturday, April 22 and 23. Technical papers will be read Friday afternoon and Saturday morning, the first session to feature a variety of topics while the latter seminar session to be devoted to high temperature materials, with three papers.

The main speaker at the banquet Friday night will be Dr. A. B. Kinzel, president, Research Laboratories, Union Carbide & Carbon Corp., on "Research, the Foundation of the Metal Industries of New England." Plant visitations will occur Friday morning to the Chapman Valve Mfg. Co. and to the American Bosch Co., arrangements being in the hands of G. E. Fox, works manager, Chapman Valve Mfg. Co., and Howard Boyer, chief metallurgist, American Bosch Co. At the former company guests will be divided into groups of ten, each headed by a guide, who will conduct them through the iron, steel and brass foundries, the weld fabrication shop and laboratories. The Chapman company will give a luncheon at Rovelli's Friday for all visitors on the Chapman plant tour. Serving as chairman of the Regional Conference is Vincent T. Malcolm, of the Chapman company.

Friday afternoon session

For the Friday afternoon technical session W. H. Sharp, Pratt & Whitney Aircraft, East Hartford, Conn., will serve as chairman. The following papers will be given: "The Influence of Composition on the Stress Corrosion Cracking of Some Copper Base Alloys," by A. W. Tracey and D. H. Thompson, both of the American Brass Co., Waterbury, Conn.; "The Gaseous Fluxing for Brazing of Steel," by Alden Edson, Hamilton Standard Propeller Div., United Aircraft, East Hartford, Conn.; "The Properties of Commercially Pure Titanium," by W. L. Finlay and E. L. Wemple, Remington Arms Co., Bridgeport, Conn.; and "Solid Phase Bonding of Aluminum to Steel," by V. W. Cooke, Pratt & Whitney Aircraft.

In charge of the Saturday forenoon seminar will be Norman Mochel, Westinghouse Electric Corp., West Philadelphia, the following to be presented: "Alloys for High Temperature Service," by R. H. Thielemann, United Aircraft Co., Pratt & Whitney Div.; "Sigma Phase in Cast Austenitic Steels," by Sidney Low, Chapman Valve Mfg. Co., Indian Orchard, Mass.; "High Temperature Research," by Ernest Robinson, General Electric Co., Schenectady, N. Y.

Three combinations of fees have been provided, as follows: Banquet, transportation for plant visitations and registration, $5; banquet and registration only, $4; registration fee only, $2.

Members of the committee for this Regional Conference are: Vincent T. Malcolm, chairman, William Mounce, George Swift, H. I. Dixon, R. S. French, Sidney Low, Howard Boyer, W. H. Sharp, G. E. Fox, Roger Sutton, Prof. Carl Johnson, John A. Swift, Weston Morrill, Prof. Carl Floe, Victor Hillman and R. L. Nichols.

Thermodynamics and Stresses Are Dealt With at Detroit

"Thermodynamics, as Applied to Physical Metallurgy," by Prof. C. A. Siebert, University of Michigan, featured the January meeting of the Detroit Section, AIME, while the February session was featured by a talk by Dr. Charles Lipson, Chrysler Corp., on "Significance of Residual Stresses in Design."

At the January meeting the speaker showed how thermodynamic concepts can be used in many everyday metallurgical applications. He indicated that some of the most useful applications of thermodynamics would be in the field of surface energy. Speaking of the graphitization of steel power piping in service, he showed how $\triangle$ F for the reaction $Fe_3C \rightleftarrows 3 Fe + C$ at 1000 F could be computed for plain carbon, carbon-molybdenum, and chromium steels on the basis of certain assumptions that are valid for indicating a trend, though not strictly accurate. For the plain carbon and carbon-molybdenum steels $\triangle$ F was calculated to be negative, indicating that Fe_3C and Mo_2C could graphitize, while $\triangle$ F for the chromium steel was positive, indicating that chromium carbide would be stable at 1000 F. The speaker applied thermodynamic calculations to the problem of purifying the hydrogen atmosphere used in brazing stainless steel, determining the activities of solid solutions, and the development of phase diagrams.

At the February meeting Dr. Lipson said that photoelastic methods are the most suitable for determining stresses where there are sharp changes in section, as in small fillets or threads. Extensometer systems are applicable to large sections. Nitriding, carburizing and induction hardening, also machining, introduce residual stresses. Plots of the case depth versus residual stress reveal the differences in stress systems produced by the several treatments.

Grinding produces tensile stresses to a depth of about 0.001 in. Using samples, shot blasting introduced compressive stress 0.035 in. deep; barrel finish, 0.005 in.; carburizing stresses penetrated to 0.250 in. Peculiarly, with induction hardened parts, a compressive stress penetrated to 0.075 in. deep, immediately below this being an area of high tensile stress; below this stresses were compressive again as the neutral axis was approached. Hence probably the failure at the interior of some induction hardened parts.

Thus heat treatment and machining must be considered in designing and residual stresses to be produced must be added to expected service load—or subtracted from the strength of the material, which is the more conventional method. Thus if straightening of crankshafts is necessary, sufficient deleterious residual stress is introduced so that the shaft will support but one-third of the expected load. Hence a safety factor of three must be added to the normal safety factor.

If the magnitude and type of residual stress and processing is known, a safety factor of two is perhaps sufficient. Some data show that understressing in service brings about stress relief and actually strengthens the part.

The following forthcoming meetings were scheduled: April 18, Electron Microscope, W. L. Grube; May 16, Metallic Sheet, A. C. Cooley.

M. SEMCHYSHEN

> The deadline for Fall Meeting papers of IMD will be May 1, 1949.

Those who take the trip to the Gary plant, Carnegie-Illinois, will see these two blast furnaces and hot blast stoves for heating 7000 tons of ore daily.

THE thirty-second annual conference of the National Open Hearth Steel Committee and Blast Furnace, Coke Oven and Raw Materials Committee, AIME, will be held at the Palmer House, Chicago, April 18, 19 and 20. Besides the usual formal technical sessions, trips will be taken through the Gary plant, Carnegie-Illinois Steel Corp. on April 18. Other special features will be the Annual Fellowship Dinner for both the Open Hearth and the Blast Furnace divisions and a luncheon of the Blast Furnace division. Another feature will be the McKune Award Paper.

The registration desks for both the Open Hearth and the Blast Furnace, Coke Oven and Raw Materials Conference will be located in the Grand Ballroom Foyer of the Palmer House. Registration will be open from 6:00-9:00 p.m. on Sunday; from 8:30 a.m.-5:00 p.m., on Monday and Tuesday and from 9:00 a.m. to 4:00 p.m. on Wednesday, April 17-20. Fees are $6 for the Open Hearth and $5 for the Blast Furnace groups to defray expenses of the Proceedings, sent gratis to all registrants. Registration for one conference admits to the other.

The reception and annual dinner will be held Tuesday, April 19, the reception and cocktail hour being held in the Exhibit Hall at 6:15 p.m. with the Annual Fellowship Dinner for both divisions in the Grand Ballroom at 7:00 p.m.

Reservations should be made to the hotel directly, being sure to mention the Open Hearth or Blast Furnace conference of AIME and probable time of arrival. The hotels prefer that members arrange to share rooms with some other member. In case of intended arrival late Sunday the hotel should be so notified, since in general they do not hold rooms beyond 6:00 p.m. unless definitely specified.

The Gary Steel Works, Carnegie-Illinois Steel Corp., known as the world's largest steel producing plant, has arranged for a most interesting plant tour on Monday, April 18. Visitors will have an opportunity to see coke ovens, blast furnaces, open hearth furnaces, 38 in. hot strip mill, wheel mill and merchant mills.

Special cars will be attached to regular trains leaving the Randolph Street Station, South Shore Electric, for Gary, Ind. Registrants may take any of the following forenoon trains: 9:00, 9:30, 10:00, and 10:30. Early departure is recommended. A luncheon will be served with the compliments of the Carnegie-Illinois Steel Corp. following approximately a two-hour plant trip.

A charge of three dollars ($3.00) is being made for the plant trip to help defray non-technical expenses at the Conference. No tickets will be sold at the Gary Works either on the day of the trip or before.

OPEN HEARTH PROGRAM
GENERAL SESSION
Tuesday, April 19
9:00 a.m.—Grand Ballroom
1. Welcoming Remarks
   By C. R. FonDersmith, Superintendent of Steel Production, Armco Steel Corp., Middletown, Ohio; General Chairman,

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ANNUAL FELLOWSHIP DINNER

Tuesday, April 19

6:15 p.m.—Exhibit Hall
Reception and cocktail hour for dinner guests
7:00 p.m.—Grand Ballroom
Annual Fellowship Dinner (Tickets, $8.00; including tax and tip.)
Toastmaster: H. J. Watt, Manager of Sales, Western Area, Carnegie-Illinois Steel Corporation
Speaker: Clarence B. Randall, Assistant to the President, Inland Steel Company
Entertainment during the dinner by the "Singing Men of Steel," a male chorus from the South Works of Carnegie-Illinois Steel Corp.

Furnace Meetings

Chicago April 18-20

National Open Hearth Committee
2. Announcements and Reports
3. McKune Award Paper

Tuesday, April 19
10:30 a.m.-12:15 p.m.—Grand Ballroom

OPERATING SESSION—I
Problems of Sulphur Elimination in Steel

Chairmen: D. R. Loughrey, Asst. Superintendent, Bessemer and Open Hearth, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

L. R. Berner, Superintendent, Steel Production, Inland Steel Co., E. Chicago, Ind.

1. Methods of Desulphurization of Pig Iron

Paper by H. M. Griffith, Works Mgr., Steel Company of Canada, Ltd., Hamilton, Ontario, Canada

Paper by E. P. Best, Plant Met., A. M. Byers Co., Ambridge, Pa.

2. Factors Affecting Sulphur in the Open Hearth Bath

Paper by H. E. Warren, Director of Steel Prod., Carnegie-Illinois Steel Corp., Homestead Works, Munhall, Pa.

3. Effect of Cold Charge and Additions on Sulphur Elimination

Paper by A. H. Osborne, Senior Metallurgist, Armco Steel Corp., Middletown, Ohio

Paper by W. H. Carpenter, Process Control Metallurgist, Colorado Fuel & Iron Corp., Pueblo, Colo.

Tuesday, April 19
10:30 a.m.-12:15 p.m.—Red Lacquer Room

ACID OPEN HEARTH OPERATIONS

Chairmen: C. F. Christopher, Metallurgical Engineer, Continental Foundry & Machine Co., E. Chicago, Ind.

H. E. Dowie, Open Hearth Superintendent, Mesta Machine Co., Homestead, Pa.

At the Gary works, Carnegie-Illinois, the "heat" is being poured into molds.

1. Metal Fluidity for a Given Steel Is a Function Only of Temperature

Paper by Guy M. Neagley, Jr., Assistant Steel Metallurgist, Pittsburgh Rolls Division, Blaw-Knox Co., Pittsburgh, Pa.

2. Late Ore Additions Are Not Detrimental to Surface Condition of Castings

Paper by F. H. Allison, Jr., Chief Metallurgist, United Engineering & Foundry Co., Pittsburgh, Pa.

3. Furnace Practice May Be Identical for Either Ingots or Castings

Paper by R. W. Devine, Plant Superintendent, Erie Forge Co., Erie, Pa.

4. Foaming Acid Open Hearth Ladle Slags Have No Connection with the Gas Content of the Metal

T. J. Ondocsin, Metallurgist, Mackintosh-Hemphill Co., Midland, Pa.

5. Either a High Rate of Carbon Drop or Melting-in on a Boil Close to "Go Ahead" Analysis Produces the Best Physical Properties

Paper by G. S. Baldwin, Chief Metallurgist, Standard Steel Works Div., Baldwin Locomotive Works, Burnham, Pa.

C. R. FonDersmith,
Chairman, N.O.H.C.

W. C. Kitto,
Past Chairman, N.O.H.C.

E. G. HILL,
Vice Chairman, N.O.H.C.

Tuesday, April 19
2:00-5:00 p.m.—Grand Ballroom

OPERATING SESSION—II

Chairmen: H. L. Allen, Jr., Asst. Dist. Mgr.,
Republic Steel Corp., Buffalo,
N. Y.

J. J. Golden, Div. Superintendent,
Steel Prod. & Central Mills,
Carnegie-Illinois Steel Corp.,
Gary, Ind.

4. **Report by Sections on Use of Oxygen and
Compressed Air**
   a. Flame Enrichment
   b. Carbon Reduction

5. **Evaluation of Factors Influencing Open
Hearth Furnace Production**
   Paper by S. F. Elam, Open Hearth Metal-
   lurgist, Armco Steel Corp., Ashland,
   Ky.

H. M. Griffith,
Vice-Chr. Elect, N.O.H.C.

Paper by A. P. Woods, Research Engi-
neer, Armco Steel Corp., Middletown,
Ohio

6. **Sampling for Oxygen in Waste Gases**
   Paper by G. C. Primm, Superintendent
   Fuel Utilization, Carnegie-Illinois
   Steel Corp., Chicago, Ill.

7. **What Is Being Done to Improve Scrap
Quality and Better Prepare It for
Charging?**
   Paper by H. A. Parker, Superintendent
   No. 2 Open Hearth, South Works, Car-
   negie-Illinois Steel Corp., Chicago, Ill.

8. **Use of Blown Metal**
   a. In stationary furnaces
      Paper by S. J. Dougherty, Metal-
      lurgical Engineer, Weirton Steel
      Co., Weirton, W. Va.
   b. In tilting furnace
      Paper by S. J. Creswell, Superin-
      tendent No. 3 Open Hearth &
      Bessemer, So. Works, Carnegie-
      Illinois Steel Corp., Chicago, Ill.

9. **Recent Developments in Hot Top Designs
and Relative Efficiencies**
   Paper by J. A. Mueller, Engineering Ex-
   periment Station, Ohio State Univer-
   sity, Columbus, Ohio

Tuesday, April 19
2:00-5:00 p.m.—Red Lacquer Room

COLD METAL OPERATIONS AND
BASIC FOUNDRY PRACTICE

Chairmen: H. S. Hall, Fuel Engineer, Lukens
Steel Co., Coatesville, Pa.

A. H. Sommer, Superintendent
Steel Plant, Keystone Steel &
Wire Co., Peoria, Ill.

1. **Scrap Preparation and Charging Practice**
   Paper by William Schwinn, Keystone Steel & Wire Co., Peoria, Ill.
   Paper by W. H. Steinheider, Open Hearth Met., Sheffield Steel Corp., Kansas City, Mo.
   Paper by R. C. Solomon, Open Hearth Supt., Granite City Steel Corp., Granite City, Ill.
   Paper by H. M. Parker, Open Hearth Supt., Armco Steel Corp., Butler, Pa.
   Paper by J. F. Richardson, Open Hearth Supt., Continental Steel Corp., Kokomo, Ind.

2. **Furnace Design for Cold Metal Shops**
   Paper by O. P. Luetscher, Consulting Engr., Keystone Steel & Wire Co., Peoria, Ill.

3. **Use of Oxygen and Compressed Air in Cold Metal Shops**
   Paper by L. L. Whitney, Open Hearth Supt., American Steel Foundries, Alliance, Ohio
   Paper by E. H. Reyer, Open Hearth Supt., Keystone Steel & Wire Co., Peoria, Ill.

4. **Use of Multiple Burners**
   Paper by R. R. Fayles, Asst. Open Hearth Supt., Lukens Steel Co., Coatesville, Pa.

5. **Bath Temperature Pyrometer**
   Paper by John Warchol, Research Engr., Lukens Steel Co., Coatesville, Pa.
   Paper by W. D. Lawther, Chief Chem., American Steel Foundries, E. St. Louis, Ill.

Wednesday, April 20
9:30 a.m.-12:15 p.m.—Grand Ballroom

METALLURGY OF THE OPEN HEARTH PROCESS

Chairmen: D. L. McBride, Supt. Open Hearth, Bethlehem Steel Co., Johnstown, Pa.
G. H. Todd, Asst. to Genl. Superintendent, Armco Steel Corp., Ashland, Ky.

1. **Deoxidation Practice for Killed Steels**
   Paper by H. J. Forsyth, Assistant Director, Steel Conservation, Republic Steel Corp., Cleveland, Ohio

2. **Deoxidation Practice of Semi-killed, Capped, and Rimmed Steels**
   Paper by Simon Feigenbaum, Research Engineer, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

3. **Mechanism of Foaming**
   Paper by B. M. Larsen, Supvr. of Process Research Metallurgy, U. S. Steel Corp., Kearny, N. J.

Wednesday, April 20
9:30 a.m.-12:15 p.m.—Red Lacquer Room

REFRACTORIES AND MASONRY

Chairmen: I. C. Johnston, Mason Superintendent, Republic Steel Corp., Youngstown, Ohio
E. B. Snyder, Refractories Engr., Wheeling Steel Corp., Steubenville, Ohio

1. **Progress Reports on Basic Lined Furnace**
   a. Complete furnace construction
      Paper by A. K. Moore, Supt., Open Hearth Works, Steel Company of Canada, Ltd., Hamilton, Ont., Canada
      Paper by M. F. Yarotsky, Supt., Steel Prod., Carnegie - Illinois Steel Corp., South Works, Chicago, Ill.
   b. Basic ends
      Paper by H. E. Warren, Dir. of Steel Prod., Carnegie - Illinois Steel Corp., Homestead Works, Munhall, Pa.
      Paper by C. R. FonDersmith, Supt., Steel Prod., Armco Steel Corp., Middletown, Ohio

2. **Mixer Linings**
   a. Special brick
      Paper by Addison Maupin, Ceramic Engr., Republic Steel Corp., Cleveland, Ohio
   b. Rammed lining
      Paper by F. A. Colledge, Supt., Masonry, Carnegie-Illinois Steel Corp., Munhall, Pa.

3. **Roof Life vs. Silica Brick Quality**
   a. Quality of silica brick
      Paper by H. M. Kraner, Research Engr., Bethlehem Steel Co., Bethlehem, Pa.
   b. The relative effect of alumina and alkalies on the refractoriness of silica brick
      Paper by L. L. Wells, General Supervisor, Ceramic Development, Carnegie-Illinois Steel Corp., Chicago, Ill.

Wednesday, April 20
2:00-5:00 p.m.—Grand Ballroom

QUALITY SESSION

Chairmen: Mark Geigel, Practice Engineer, Youngstown Sheet & Tube Co., Youngstown, Ohio
J. R. Brady, Supvr., Res. and Testing Dept., Wisconsin Steel Works, Chicago, Ill.

1. **Single Objective Safety**
   Paper by D. A. Farrell, Supvr. Safety, Carnegie-Illinois Steel Corp., Chicago, Ill.

2. Advantages and Disadvantages of Mechanically Capped Ingots
   a. Ingot structure and surface quality
   b. Yield compared to rimmed steel
   c. Physical characteristics
      Paper by O. Pearson, Chief Metallurgist, Carnegie-Illinois Steel Corp., Gary, Ind.

3. Effect on Quality of Elapsed Time Between Last Oxygen Injection and Tapping
   Paper by C. G. McCabe, Foreman, Open Hearth Metallurgy, Wheeling Steel Corp., Steubenville, Ohio

4. Effect of Nitrogen in Improving the Physical Properties of Low Carbon Steels
   Paper by S. C. Faddis, Assistant Metallurgist, Pittsburgh Works, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

5. Effect of Residuals on Surface Quality
   Paper by J. G. Althouse, Metallurgical Engineer, Lukens Steel Co., Coatesville, Pa.

6. A Study of Factors Affecting Surface Quality of Various Steel Products
   Paper by L. R. Walker, Chief Metallurgist, Edgar Thomson Works, Carnegie-Illinois Steel Corp., Braddock, Pa.

BLAST FURNACE, COKE OVEN, RAW MATERIALS

Tuesday, April 19
9:30 a.m.-12:15 p.m.—Room 14

GENERAL SESSION

Chairmen: C. P. Betz, Asst. Manager Blast Furnace Div., Great Lakes Steel Corp., Detroit, Mich.

M. D. Wald, Asst. District Manager, Republic Steel Corp., Cleveland, Ohio

1. **Effect of the Coke Stability on the Operation of the Blast Furnace**
   Preprinted paper by J. F. Peters, Asst. Superintendent Blast Furnaces, Inland Steel Co., E. Chicago, Ind.

2. **Reducing Coal Expansion Pressure**
   Paper by C. C. Russell, Chemical Engr., Michael Perch, Chemical Engr., and J. F. Farnsworth, Chemical Engr., Research Dept., Koppers Co., Inc., Kearny, N. J.

3. **New Design of Equipment for Recovery of Ammonium Sulphate**

Paper by Hans Otto, Otto Construction Corp., New York, N. Y.

Tuesday, April 19
2:00-5:00 p.m.—Room 14

OPERATING SESSION

Chairmen: R. A. Lindgren, Genl. Superintendent, Wisconsin Steel Works, International Harvester Co., Chicago, Ill.

W. S. Unger, Consulting Engineer, Carnegie-Illinois Steel Corp., Pittsburgh, Pa.

1. **Operating Differences Between Large and Small Furnaces**
   Paper by J. M. Stapleton, Asst. Div. Supt., Blast Furnaces, Carnegie-Illinois Steel Corp., Chicago, Ill.
   Paper by G. P. Burks, Div. Supt., Blast Furnaces, Carnegie-Illinois Steel Corp., Gary, Ind.
   Preprinted paper by J. Knox Dye, Supt., Blast Furnaces, Armco Steel Corp., Ashland, Ky.
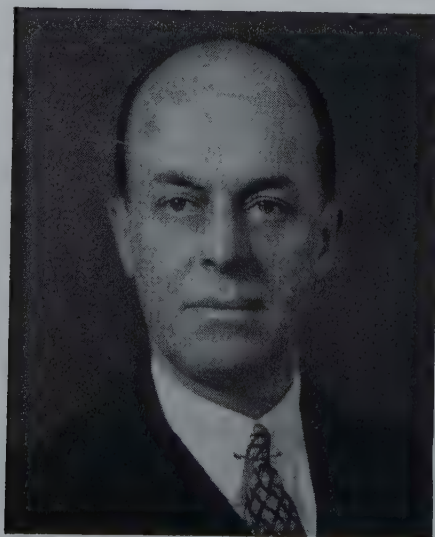
W. S. Unger, Secretary
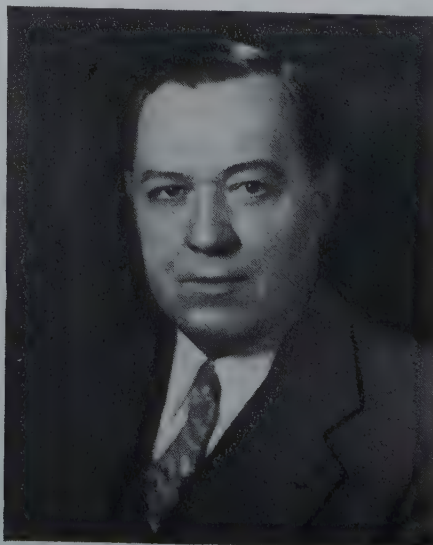
R. W. Campbell, Chairman,
Papers Sub-Committee

E. F. Mitchell, Chairman,
Finance Sub-Committee

Paper by T. F. Plimpton, Supt., Blast
Furnace Dept., Inland Steel Co., E.
Chicago, Ind.

Paper by C. F. Hoffman, Supt., Blast Fur-
naces, Bethlehem Steel Co., Sparrows
Point, Md.

Tuesday, April 19
2:00-5:00 p.m.—Room 17

COKE PLANT SESSION

Chairmen: R. W. Campbell, Superintendent,
Coke Dept., Jones & Laughlin
Steel Corp., Pittsburgh, Pa.

B. A. Standerline, Superintendent,
Coke Plant, Wisconsin Steel
Works, Chicago, Ill.

1. Rehabilitation of Coke Ovens

Paper by W. D. Spaulding, Supt., Coke
Plant, Weirton Steel Co., Weirton,
W. Va.

Preprinted paper by F. L. McIntire,
Supt., Pittsburgh By-product Coke
Plant, Jones & Laughlin Steel Corp.,
Pittsburgh, Pa.

Paper by P. C. Mayfield, Supt., Coke &
Chemicals Div., Alan Wood Steel Co.,
Conshohocken, Pa.

Paper by Elliott Preston, Genl. Supt.,
Engrg. & Construction Div., Koppers
Co., Inc., Pittsburgh, Pa.

Wednesday, April 20
9:30 a.m.-12:15 p.m.—Room 14

AGGLOMERATING SESSION

Chairmen: K. C. McCutcheon, Asst. to Vice-
President, Armco Steel Corp.,
Ashland, Ky.

Fordyce Coburn, Executive Vice-
President, The E. & G. Brooke
Iron Co., Birdsboro, Pa.

**1. Manufacture of Nodules from Fine Ore
and Limestone at Buffalo, N. Y.**

T. L. Joseph, Chairman

Preprinted paper by A. A. Oesterle, Genl.
Supt., Federal Portland Cement Co.,
Inc., Buffalo, N. Y.

**2. Manufacture of Nodules in Ironton, Ohio,
Using Mesabi Fines and Blast Furnace
Flue Dust**

Preprinted paper by E. F. Brownstead,
Asst. Genl. Supt., Alpha Portland Ce-
ment Co., LeMay, Mo.

**3. Operation and Practice, Producing Iron
Sinter at Ducktown and Copperhill,
Tennessee, with Fine Flotation Sul-
phides**

Preprinted paper by R. R. Burns, Asst.
Smelter Supt., Tennessee Copper Co.,
Copperhill, Tenn.

**4. Briquetting Practice on Fine Ores at
Woodward, Alabama**

Preprinted paper by H. A. Byrns, Genl.
Supt., Woodward Iron Co., Woodward,
Ala.
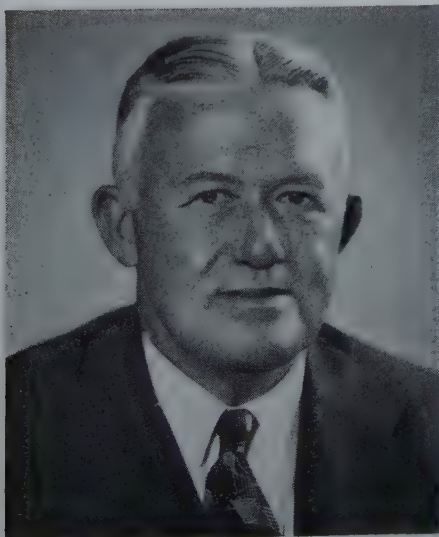
C. L. Wyman, Vice-Chairman
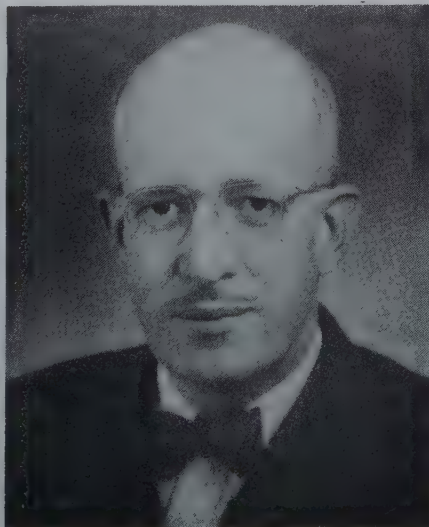
T. F. Plimpton, Vice-Chairman
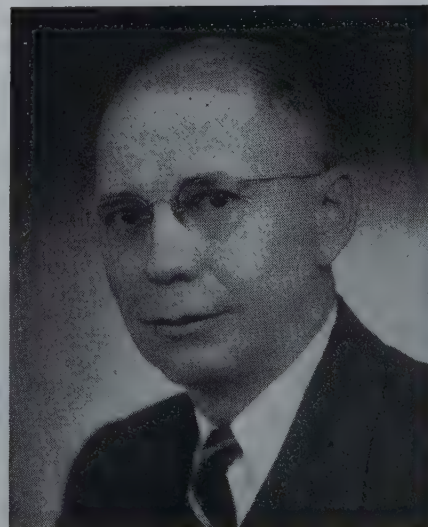
E. J. Gardner, Chairman
Program Sub-Committee

Western Open Hearth

A summary has been prepared of recent meetings of the Western section, National Open Hearth Steel Committee, AIME. The October session was more than usually packed with a wealth of technical material. Thus a paper on "Open Hearth Quality Control," by C. A. Rogers, Kaiser Co., Inc., covered various methods of statistical quality control as practiced by Kaiser Co. at their Fontana plant. "Use of Gaseous Oxygen in Electric Furnace Steelmaking" was dealt with by Edmund J. Goehring, National Cylinder Gas Co., having been a summary of the work done by that company in the application of gaseous oxygen to decarbonization.

A third paper was on "Electric Steel Furnace Practice at General Metals Corp." by Philip McCaffery of that corporation, being a presentation of how steel is made at the Oakland plant of that concern. "Compressed Air Versus Oxygen in the Open Hearth" was the subject of William H. Carpenter, Colorado Fuel & Iron Co., dealing principally with experiences with compressed air as a decarbonizing agent in the open hearth at his company. William A. Green, Kaiser Co., was assigned the subject, "Methods of Analyzing Refractory Consumption," the paper showing some interesting methods of evaluating refractory life and consumption. The Electric Furnace Steel members joined in this and subsequent meetings. A cocktail party and dinner followed.

At the session in November the topic was "Resources of the Western United States," by George McMeans, Kaiser Co., Inc. The paper gave the geological picture and covered chiefly coal and iron ore deposits that may be opened for western consumption. The December meeting was a General Discussion Session devoted to production problems. In January two moving pictures were presented by the National Supply Co. through the courtesy of Allegheny Ludlum Steel Corp. One was on the manufacture of stainless steels and the other on tarpon fishing off the Florida Coast (at which we assume that some stainless steel was used in some of the fishing gear). No meeting was held in February because of the annual meeting of AIME at San Francisco that month. Scheduled for March was J. A. Kayser, LaClede-Christy Co. on "Observation on Refractory Applications."

J. T. EVANS, JR.

B. G. Emmett, Chairman, Western Section NOHC.

T. T. Watson, Chairman, Eastern Section
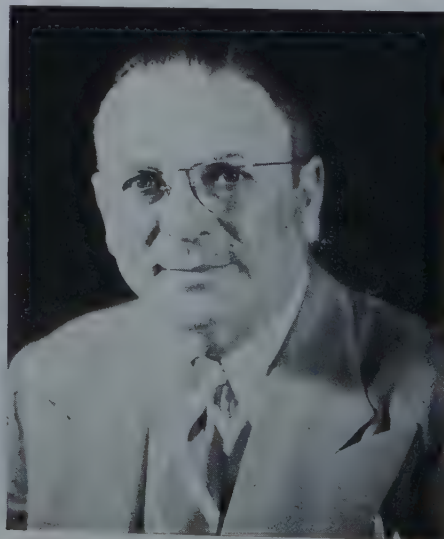
T. A. Cleary, Chairman, Northern Ohio Section.

Southern Ohio Open Hearth

The Southern Ohio Section, Open Hearth Committee, AIME, joined with the Ohio Valley Section, AIME, to combine technical sessions with football at Columbus Oct. 1 and 2, with 284 registered the first day as against 296 the year before. The Open Hearth and Ohio Valley Section held separate morning meetings, joining for a Metallurgical and Quality meeting the first afternoon. The Open Hearth meeting was as usual "off the record" and included the following papers: "Current Report on Progress of Basic End Furnaces," by E. R. Westfall; "Some New Factors Affecting Open Hearth Production," by A. T. Woods; "Some Factors Affecting Sulphur Control of Open Hearth," by Arthur Osborn, and "Recent Advances in Hot Tops," by John W. Mueller.

The dinner, held the evening of the first night, was attended by 181, including many wives of members. Serving as toastmaster was Gilbert Soler, works manager, Atlas Steel Co., Welland, Ont., while the speaker was John E. Dolibois, alumni executive secretary, Miami University, Oxford, Ohio, on "Experiences as an Interrogator of High-Ranking Nazi War Criminals." Honoring the dinner by their presence, were the chairman, vice chairman and two past chairmen of the National Open Hearth Committee.

On Saturday morning, Oct. 2, a meeting of the executive committee of the National Open Hearth Committee was held, while in the afternoon the group attended the Ohio State-Southern California football game.

The 1949 meeting will again be held at the Deshler-Wallick Hotel on Sept. 30 and Oct. 1, just following the Regional Meeting of AIME sponsored by the Ohio Valley Section. The football game will be Ohio State vs. Indiana.

Southwestern Section, NOHC Meets at St. Louis

A regular meeting of the Southwestern Section, NOHC, was held on Feb. 12 at the Lennox Hotel, St. Louis, with 94 persons including representatives from Colorado Fuel & Iron Corp. at Pueblo, Sheffield Steel Company at Kansas City and Keystone Steel & Wire Co., Peoria, Ill.

A comprehensive program including five major topics began at 10:30 a.m. and continued until 5:45 p.m.

Open Hearth problems pertaining to Furnace Charging Time and Scrap Preparation and the Use of Oxygen in Open Hearth Practice consumed a major portion, with Furnace Design for Bulky Scrap, and the Use of Basic Brick for Furnace Construction, also discussed.

One plant, where various types of scrap is used including 18-in. lengths for cupola charging, related the use of special equipment for preparing scrap, which included a large torch which involves the use of a flux for cutting scrap up to 5 ft. thick. With the use of a charging box 2 ft. x 2 ft. x 7½ ft. long, they were able to prepare scrap to a density of 25-35 pounds per cu.ft. The time required for charging 190,000 lb.

of steel scrap and 90,000 lb. of hot cupola metal averages 5 hrs. in this shop. With 8-10 buggies constituting a cut of scrap, 4 cuts are required to handle the cold portion which consumes 4 of the 5 hrs. average charging time.

In another shop where coke was used to replace a considerable percentage of pig iron, an average charging time of 7 min. 14 sec. was reported. These heats required the use of 65 buggies

M. F. Yarotsky, Chairman, Chicago Section, and Chairman, Local Committee for 1949 National Meeting of N.O.H.C.

Other Meetings

Other sectional reports appeared in Sect. 1, January issue: The Eastern section, Page 16; Pittsburgh, Page 17; Chicago, Page 16.
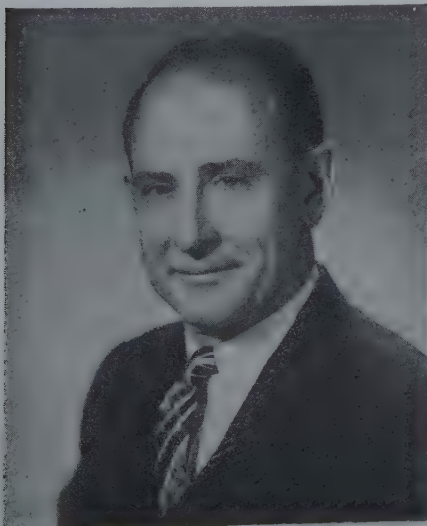
A. H. Sommer, Chairman, Southwestern Section

R. S. Bower, Chairman, Southern Ohio Section

A. W. Thornton, Chairman, Pittsburgh Section

holding four boxes each to charge 365,-000 lb. of scrap. By instituting an incentive plan for increased weight per buggy and making it mandatory for the stock foreman to explain any charging time over 6 hrs. and 30 min., the charging time in this shop was reduced within several months' time to 6 min. 7 sec. using the same type of charge. In the same shop in December by eliminating coke and substituting pig iron, they reported an average charging time of 5 hrs. and 20 min. A special means of handling No. 2 heavy melting steel by filling the charging boxes after setting them on the ground under a gantry crane was given considerable credit for this reduction of charging time. This method of handling scrap includes the use of a special yoke to pick up four charging boxes at a time was also credited with increasing the net weight per charging buggy from 4259 lb. to 5151 lb.

Installing more trackage and the purchase of additional cars and boxes along with the use of oxygen has increased the total output as much as 20 per cent in this shop.

Oxygen has resulted in increased output in some plants. A basic steel foundry operating 30-ton furnaces and using oxygen for flame enrichment and carbon reduction reduced total heat time by 20 per cent and over a three-months' period averaged 3 hrs., 57 min. per heat. They reported no deterimental effects to refractories after using a water cooled multiple opening lance which is immersed 7 sec. into the molten bath for carbon reduction. The total reduction in heat time was given as 50-55 min. and oxygen was considered more practical than compressed air with an all cold charge due to a greater temperature rise and less pig iron being needed to produce a certain carbon range.

An ingot shop operating three 170-ton open hearths using oxygen through a lance for carbon reduction and temperature pick-up reported other benefits besides increased output. Although the effect may be indirect, their sulphur problems have been very much minimized by the use of oxygen. The advantages as to the use of oxygen in this plant include a reduction of 400,-000 Btu's in fuel consumption and approximately one hour saving in time from tap to tap. Although individual heats have shown a production rate of 17.5 tons per hr. the sustained possible tonnage rate for the shop is approxi-

mately 14 tons per hr. as compared with 12¾ tons per hr. before oxygen was used. The intermittent use of oxygen or operating a furnace one week without oxygen and one week with the use of oxygen is now being practiced in this shop, in order to determine its practicability. The sustained use of oxygen has decreased roof life approximately 30 per cent in the ingot shop.

As to furnace design to facilitate charging and melting large percentages of scrap, it was agreed that it should be somewhat different than a shop using a large percentage of hot metal. Some of the features discussed were a higher roof over the bath and the elimination of knuckles and monkey walls. Archless frames and much larger door openings were considered essential along with artillery type burners which could be adjusted downward as the scrap melted down. More water cooling is found to be advantageous for the frontwall and skewbacks on furnaces with a high roof using a high percentage of scrap.

Two companies producing semi-killed low carbon steel agreed that final deoxidation should be done in the ladle and that a narrow range exists between over and under deoxidation. If the steel has been properly deoxidized, the top of the ingot was described as showing a slight bulge, but with over deoxidation, the top would be concave. In one plant, water is used to help control and produce the desired ingot top condition. This type of steel was described as needing special care when being heated in the Soaking Pits to prevent washing.

As to the use of basic end furnaces, at the present time, only three furnaces have been built in this area. With this type of construction with varied results as to their advantages in one plant, it resulted in better furnace life with a slightly higher fuel consumption while in another plant slightly lower fuel consumption was reported along with increased furnace life. The advantages such as easy removal of slag and less down time were stressed in all cases.

A. H. SOMMER

Northern Ohio, NOHC, AIME Hears Four Technical Papers

Four technical papers were presented at an off-the-record meeting of the Northern Ohio Section, NOHC, AIME, at Youngstown, Ohio, on Feb. 13. W. S.

Debenham, Carnegie-Illinois Steel Corp., discussed: "Effect of Certain Variables on Roof Life." Comparing standard brick with super duty brick, he found the latter did not melt at 3000 F and increased in density from 0.4 to 0.86 where the standard brick showed a great amount of deterioration. Decreasing the amount of alumina in the refractory increased the life of the brick. If we insulate a furnace with good material, we can attain good results only if we control temperature carefully. It is important to reach the critical temperature as soon as possible; also very important to maintain a uniform temperature throughout the campaign.

Discussions brought out some of the following statements. No definite answer was given for maximum temperature allowed on a roof, but 3000 F was recommended for steady operation. There is a definite relation between lime and other impurities in the brick. The brick might reach a point of oxide saturation or might melt behind the hot face, causing chunks to drop off without any signs of burning, or the formation of stringers or lace curtain effect. The main cause of roof trouble can be traced to the operators, the main failings being overheating and failure to maintain a uniform temperature.

Russel H. Farr, Youngstown Sheet & Tube Co., dealt with "Use of Immersion Pyrometers in the Open Hearth," describing the installation and operating technique of the three pyrometers at the Brier Hill plant. A film demonstrated the construction of the pyrometer. The cost per unit is around $1,205; average cost of reading is 10 cents.

Among the statements in the discussion were the following. Procedure should be standardized, the temperature to be taken in the same way and in the same door at every reading. Furnace temperature should be checked against the runner temperature so that the gun can be set at some standard at the shop where it is being used. Ten minutes should elapse between each reading, the tube to be kept in the bath no longer than 10 sec. Benefits of the immersion pyrometer are reduction of skulls, reduction of clean ladles which improved ladle life and mold life. Nearly all present have immersion pyrometers and said they improved open hearth practice.

A. B. Wilder, National Tube Co., discussed, "The Acid Bessemer Process in the Production of Bessemer Seamless

Tube Pipe." He said that the deoxidation practice is the most important part of the operation, the pipe caused not being an important factor. The original cost of the plant is less than that of the open hearth, as is the operation cost, while the yield is about the same. The product has a high collapse resistance, toughness of impact equal to that of open hearth products, weldability properties are very good and no difficulties are met regarding the fabricators.

The discussion brought out that coal or graphite can be used as a recarb, but hot metal is more effective. FeMn and FeSi are added to the vessel through a chute, so designed that the material will penetrate the slag surface.

W. E. Coleman, Republic Steel Corp., discoursed on "Effect of Charge Ores and Other Oxides on Yield and Production." He explained with the aid of charts four types of ore he tested against their regular practice. Magnetite fines were made into 8-in. cubes, resulting in better yield, less loss during flushing, (about 1 per cent), with an increase in tons of 2 per cent and decreased heat time, 1½ per cent.

Standard sinter, 68 per cent iron, 6-in. to fine, had good chemistry but poor physical properties, resulting in a slight increase of tons per hour and a slight decrease in heat time. Lump ore, 68 per cent iron, under 3 per cent silicon, gave results about the same as for the previous sample. Lump ore, 55 per cent iron, 8 per cent silicon, had poor chemistry but good physical properties, resulting in 10 per cent increased heat time and decrease by 10 per cent in tons per hour.

Summarizing, Mr. Coleman said that varieties in physical properties and chemistry have a great effect on open hearth production. It is possible to get by with fair chemistry if physical properties are tops. It is economical to use foreign ore, while present-day conditions of a lighter scrap and finer ores present a problem that must be overcome.

Doll Talks on Beryllium, Titanium and Zirconium

The Cleveland section, AIME, listened to a talk on "Some Metallurgical Characteristics of Beryllium, Titanium, and Zirconium" by Denton T. Doll, of Brush Beryllium Co. on Feb. 17, held at the Case Institute of Technology and attended by 50 persons. The speaker pointed out that these metals are receiving considerable attention from several investigating groups and promise to appear in far greater usage in the not too distant future.

He gave a brief history of past and present methods for obtaining these metals, almost in their pure state. He explained in detail the outstanding difficulties encountered and the high price of processes used to overcome these difficulties. Though limited in the scope of his talk by the tight censorship of the Atomic Energy Commission, Mr. Doll was able to present an exceedingly interesting resume concerning the production and end use of the metals.

He said that some of the previously published data on some of these metals, especially beryllium, is incorrect because the higher purity metal had never been isolated until recently, hence certain properties were surmised rather than proved. Mr. Doll told how application of powder metallurgy technique is used in obtaining these metals. In the active discussion some questions bordered on censored facts, hence were not answered completely.

VERNON F. KALAN

Bessemer Process Subject Of Chicago AIME Meeting

"Recent Developments in the Bessemer Process" was the subject of a talk by S. J. Creswell, superintendent, No. 3 open hearth and Bessemer, South Works, Carnegie-Illinois Steel Corp., before the Chicago Section, AIME, at the Chicago Bar Assn. Feb. 2. The meeting was attended by around 125 persons, including many prominent blast furnace, Bessemer and open hearth furnace operators in the Chicago district.

Acting as technical chairman and leading the lively discussion which followed the paper was L. R. Berner, superintendent of steel production, Inland Steel Co. New officers of the Chicago section for the ensuing year were introduced by the retiring section chairman, H. R. Herder. T. S. Washburn, the new chairman, extended greetings to the group and expressed hope for continued growth and interest over the coming year. H. A. White is the new secretary-treasurer.

M. E. NICKEL

BOOK REVIEWS

Elasticity and Anelasticity of Metals. By C. Zener. University of Chicago Press. 1948. $4. 170 p.

REVIEWED BY R. SMOLUCHOWSKI

Elasticity and plasticity are common notions in practically every problem of engineering. The frequently used—and misused—assumption that the material is continuous and isotropic, leads to elegant mathematical formulae which fail whenever the true physical structure of the metal begins to play a role. The amount of such experimental data is enormous and little progress in that field can be expected unless the necessary physical theories are developed. From this point of view the appearance of Dr. Zener's book is an event of greatest importance. Dr. Zener's name is associated with nearly every major development in the field of anelasticity of metals and thus the present volume is indeed an authoritative presentation of the subject. The book is not a text book—it is a monograph: it assumes a fair amount of knowledge of metallurgy, physics, and engineering and it deals primarily with Dr. Zener's own investigations. Thus, for instance, dislocation theory is only mentioned. On the other hand a large part of the material either has never been published before or at least, never presented in such a critical and connected form.

After a brief summary of elasticity (first quarter of the book) the author gives a systematic and thorough presentation of the field of anelasticity. More than three quarters of this main part of the book are devoted to physical interpretation of anelasticity and it is here that the whole beauty and value of theory in relation to experiment comes to light. In this part the various chapters deal with: thermodynamical variables and potentials, relaxation by thermal, atomic and magnetic diffusion, relaxation of ordered and preferential distributions, two—component systems, relaxation along previously formed slip bands, relaxation along grain boundaries and across twin boundaries, Everyone of these chapters inspires diverse new experimental and theoretical investigations.

The book should be wholeheartedly recommended not only to those who already work in that field—for them it is a "must"—but also to all those who are anxious to bridge the wide gap be-

Metals Branch, AIME, at Annual Meeting

Reports of Technical Sessions of Three Divisions

Affairs of the Metals Branch of AIME were conspicuous in the program of the annual meeting of AIME at San Francisco in the middle of February. There were 28 sessions, including technical papers, luncheons and lectures. The number of papers were over 65 and usually the formal papers were followed by lively discussions. Nor were those who discussed papers shy in taking exception to theories.

A surprising number of members of the Metals Branch crossed the Continent, often through blizzards and in snow-bound trains, to attend this highly successful meeting on the Pacific Coast. One of the main events was the Institute of Metals Div. lecture by Egon Orowan, Cavendish Laboratory, Cambridge, England, on the subject: "Structure of the Cold-worked Metal." Equally well-received was the Howe Memorial Lecture on "What is Metallurgy?" by John Chipman, Head, Department of Metallurgy, Massachusetts Institute of Technology. In place of the usual Institute of Metals Division Dinner and the Iron and Steel Division Luncheon a very successful Metals Branch Luncheon attended by an even one-hundred inaugurated the formation of the Metals Branch.

The time was so occupied with formal events that there was but little chance to see the sights for which San Francisco and environs are noted, but some managed to squeeze in some time and others either arrived before the annual meeting or remained after to catch up with their geography.

EXTRACTIVE METALLURGY DIVISION

Because it was the first meeting of the newly-organized Extractive Metallurgy Division, especial interest was shown at the Monday afternoon session where the published subject had been

lead and zinc. However, with the exception of the papers on the lead and zinc industries of Germany, the session could well be termed an all zinc-cadmium meeting. The meeting was called to order by Dr. Carleton Long, with the 65 attendants making up a very enthusiastic audience. Very well received were the two papers on the Risdon Works in Tasmania, covering new developments in the electrolytic zinc plant and recovery of cadmium, by L. P. Davidson and Walter Woolf. A spirited discussion followed.

"Cap" Hanley had a field day discussing trees, rotating cathodes and thallium removal. The American practice for cadmium recovery was clearly presented by M. M. Neale and Harold Lee, the former explaining the practice at Donora, Pa., the latter dealing with the operations at the Bunker Hill & Sullivan refinery, together with comparative data from other United States refineries. Two guests, A. R. Gordon of the Risdon Works, and Ken Morgan, Imperial Smelting Works, Avonmouth, England, contributed an international flavor to the discussions dealing with particular problems at their respective plants.

To avoid payment of overtime to the hotel, a halt was called to the proceedings at a late hour, those present realizing that the new division was off to a good start.

An interested audience of 70 attended the all-smelter session on Tuesday morning to hear and discuss four timely papers dealing with roasting and smelting of lead and zinc ores. Paul Feddersen, chairman-elect, Lead-Zinc Committee, presided. Art Collins of the Chihuahua smelter, led off on the effect of high copper content on a blast furnace charge and subsequent drossing of the lead bullion. Considerable discussion ensued due to the variation in price among the several

smelters. The long-awaited paper on oxygen enrichment in the metallurgical operations at the Trail plant was presented by T. H. Weldon. This plant has 3000 C.F.M. available for enrichment in the zinc roasting operations, able to produce 8.5 per cent SO_2 gas. Oxygen-enriched air in the blast furnace indicated a 10 per cent coke reduction. Also, oxygen-enriched air increased fuming rates on the zinc slag fuming unit and experienced lower than average zinc content in the treated slag.

W. Spencer Reid's paper on concentration of SO_2 content of the Dwight-Lloyd sintering machine gas by recirculation created keen interest, being novel, and a contribution to lead smelting metallurgy. The Selby plant, under guidance of E. P. Fleming, has pioneered recirculation of D & L gases, the description having brought forth praise from smelter men present. The concentrated recirculated gas is used for the production of sulphuric acid and liquid sulphur dioxide. Low-grade gases escape up the highest stack in the world, 605 ft. tall.

H. J. Najarion, of the Josephtown organization, presented a paper on "Autogenous Roasting of Low-grade Zinc Concentrated in Multiple-hearth Furnaces at Risdon, Tasmania, bringing to light the intricate mechanics of the Risdon roaster. Hereafter, pitch of teeth, slope and r.p.m. of roaster arms will have a fuller meaning to those who heard the author explain a very difficult treatise on multiple-hearth roasters.

round table discussion

A Round Table Discussion on Blast Furnace Charge Preparation and Dross Treatment occupied the Wednesday morning session. The affair was conceived, organized and executed by Ronnie McNaughton of Trail, B. C.

A feature of the meeting was that the "brains" of the lead smelting industry were 'all present under one roof. When a symposium on lead was first suggested there was doubt whether it would prove successful, but doubts were dispelled as the program proceeded. Among those who had agreed to discuss sinter feed preparation and bullion dross treatment were Art Collins, Chihuahua American Smelting & Refining plant; Casper Nelson, U. S. Smelting, and E. P. Fleming, American Smelting & Refining Co.

Representatives of the large smelting units really "let their hair down" and when the slightest hesitation in proceedings took place Ronnie dug the spurs in. It was in fact difficult to break up the meeting of 65 eager men. Long after adjournment groups lingered to carry on the discussion. The chairman for 1950 will have trouble withholding symposia from the program, as several such ideas are under way at the present.

Retorts and Equipment were the subject for the Wednesday afternoon session, administered for forty persons by L. P. Davidson, chairman, and T. D. Jones, associate chairman. H. R. Page and A. E. Lee, on the development of the modern zinc retort, stressed the integrity of this refractory receptacle as a leading characteristic in the distillation of zinc. Starting with the hand-made Belgian retort, it evolved to hydraulic fabricating equipment operating at high pressures, the substitution of silica flow for part of the non-plastic grog, de-airing the mix and, more recently, accelerated drying by air currents containing progressively decreasing humidity. We now have a retort of great beam strength, high density to resist absorption of vapor, less cracks for vapor leakage and longer life.

The silicon carbide retort succeeds the one of refractory clay component and, though costly, has proved economical in practice with many types of charge and with a knowledge of operating characteristics. Prerequisites are particle size distribution of silicon carbide grains in the mix, restriction of salt in the ore-charge and firing under reducing conditions.

Arthur D. Terrell, a long-experienced zinc metallurgist, initiated the discussions and reviewed the history of the art of zinc distillation through the years. Ken Morgan, Avonmouth, England, commented on the differences of European, English and American clays, the last being more plastic than the other two. Laminations in the retort wall occur occasionally and holing by corrosion is less frequent. For Avonmouth conditions de-airing of clay has not been found advantageous. Charles R. Kuzell, Phelps Dodge Corp., asked about retort porosity and absorption of zinc vapors to retort walls and the possibility of making a retort of super-refractory, such as pereclase.

M. M. Neal presented the second paper, prepared by R. R. Furlong and Donald Wertz, all of Donora Zinc Works, American Steel & Wire Co. Stress was given to rapid drying through automatic control of humidity by valves, a system that reduces the drying time from 45 days to 4 days, with no failures due to the speed.

Gunnard Johnson, general manager, Eagle Picher Co., East Chicago, Ind., dealt with the development of muffle furnaces for the production of zinc oxide and zinc, this having been the first formal paper on such units used to treat worn-out die castings and similar alloys. Heat for vaporizing the zinc flows through a silicon carbide arch, tightly sealed, with recovery of copper from the residue in the melting furnace part of the process. Ken Morgan and F. E. Weldon discussed the paper.

The last paper of the session described the slag treatment plant at El Paso, authored by T. J. Woodside, superintendent, El Paso Smelting Works, A. S. & R. Co. The general characteristics: Blowing time, 100 min.; coal consumption 0.23 slag, or 2.1 zinc distilled; zinc in original slag deplated from 13 per cent to 1.8 per cent; recovery of zinc, 90 per cent. General operations follow Bunker Hill practice, while de-leading of the oxide is similar to that of the Toole plants.

titanium

The session on Titanium was devoted to processing ilmenite and titaniferous ores to produce intermediate products that might be used in the production of titanium pigments or titanium metal. A few introductory remarks were made by O. C. Ralston,

SPEAKERS' TABLE AT METALS BRANCH LUNCHEON

Left to right, E. Kirkendall, Secy., Metals Branch; John Chipman, Vice Chr.-elect ISD and Howe lecturer; W. E. Brewster, Director AIME; T. B. Counselman, Vice Chairman, ISD; A. A. Smith, Jr., Chairman, IMD; W. E. Wrather, President, AIME; John Sullivan, Chr. Extractive Met. Div.; Earle Schumacher, Director, AIME; F. N. Rhines, Chairman-elect, IMD; Carleton C. Long, Chairman-elect, Extractive Met. Div.

chief, Metallurgical Branch, U. S. Bureau of Mines. The four formal papers were contributed by the Titanium Div., National Lead Co., though the fourth on pilot plant smelting of ilmenite was a joint paper by National Lead and the Bureau of Mines, all four papers forming a symposium.

The first paper was a fundamental study on the system $TiO_2 \cdot CaO \cdot MgO \cdot Al_2O_3$ and served as a basis for subsequent smelting of titaniferous ores. Melting equilibria were presented to show the region of fluid melts. An eutectic was established at 60 mole per cent of $MgO \cdot 2TiO_2$ and 40 mole per cent of $CaO \cdot TiO_2$. The second paper was devoted to laboratory smelting. Ilmenites having 38 to 44 per cent TiO_2 were smelted to produce slags of 65 to 69 per cent TiO_2. Tests in an induction furnace were correlated to single phase arc furnace tests. The third paper dealt with the petrology of high-titanium slag, as covered by the first two papers. The phase changes, with changing composition, helped to interpret the smelting results. The fourth involved pilot plant smelting of ilmenite in an electric furnace at Boulder City in which charges containing as much as 2000 lbs. of ore were smelted. A lively discussion followed.

The Thursday afternoon session was concerned with Aluminum, Copper and Zinc. The first paper, "Reflections on the Electrolytic Cells Used in the Production of Aluminum," was given in abstract by J. D. Sullivan and contained much pertinent information that will interest those concerned with aluminum production. Since the paper had not been preprinted, it was impossible to discuss numerous operating data.

An excellent description of the Morenci smelter was given by L. L. McDaniel, many questions having been asked relative to details of plant and equipment. Being the most modern copper smelter in the country, practices are of great interest to all copper producers.

The paper on Continuous Casting by J. S. Smart, Jr. and A. A. Smith, Jr., described the plant and procedures for the production of continuously cast copper and copper-base alloys. The plant produces rods, tubing, rectangles and other shapes with unusually good physical properties. Produced in long lengths, it can be used in automatic screw machines, materially lowering production costs of bearings and bushings. Frank F. Poland presented the paper, "Distillation of Zinc from Copper-base Alloys and Galvanizers' Drosses," describing a unique type of electric furnace for the distillation of zinc. High recoveries of zinc can be obtained, with appreciable savings in cost.

IRON AND STEEL DIVISION

This division got off to a good start with a session on "Sulphur in the Coke Oven and Blast Furnace." The widespread interest in the subject gave rise to spirited discussions of the three well-received papers, but the picture presented to the audience was not a cheerful one. Apparently, though the present situation with regard to sulphur in coke and in blast furnace iron is bad, it's going to get worse. It is apparent that the only way to produce low sulphur coke is to lower the sulphur content of the coal, but unfortunately the trend is in the other direction, with no indication of reversal or leveling off.

There was much discussion of variables affecting the sulphur content of blast furnace iron. Factors affecting the slag-metal sulphur ratio were studied, using operating statistical data and laboratory experiments. There was disagreement between the two approaches, particularly with regard to the importance of MgO and Al_2O_3 in the blast furnace slag. Brower and Larsen found that MgO content of the slag was important, but that variations in Al_2O_3 content, within the limits encountered, did not affect the sulphur content. Yet Hatch and Chipman, nearly reaching equilibrium conditions in their laboratory studies, found that MgO is only about two-thirds as effective as CaO in desulphurization; Al_2O_3 behaved like SiO_2 in reducing the desulphurizing power of basic slags and, therefore, is an important consideration. Various operating men stated that no one factor controls sulphur content of blast furnace iron. From discrepancies in the performance of different furnaces it is apparent that the following factors are all important and correlated: Basicity of the slag, sulphur burden, source of sulphur (from coke or ore), manganese and silicon contents, etc. The consensus was that the only sure way of producing low sulphur iron is to use low sulphur raw materials. Apparently sulphur problems are here to stay.

Monday afternoon was devoted to a session on Steelmaking, with papers followed by much discussion and apparent interest. A paper by D. C. Hilty on "Carbon, Chromium and Temperature Relations" departed from classical treatment of equilibrium studies by the author's assumption of a solid inactive CrO phase. However, the subject was handled otherwise by orthodox physical, chemical and thermodynamic concepts. Credence was placed on Mr. Hilty's attack because the results found in actual practice, basic and acid, closely match actual electric furnace experience with high chromium steels.

Dr. Sims' paper on "Hydrogen Effects on Cast Steel Ductility" was thought provocative and educational. The improved analytical procedures for

Left to Right, W. E. Wrather, President, AIME; A. A. Smith, Jr., Chairman, IMD; and Egon Orowan, receiving certificate presented to the IMD annual lecturer.

hydrogen made this study significant and will provide assistance, no doubt, in the study of many more hydrogen problems at the steel plant. The strong tendency of hydrogen to segregate to the center of small cast test coupons was not anticipated prior to this study.

Dr. Hultgren's paper on silicate inclusions developed discussion of possible mechanisms that might account for the increase in size and type of inclusions after tapping and pouring and that more work needs to be done in this field.

clad steels

At the Wednesday morning session T. T. Watson presented a paper describing the various methods of manufacture, and properties, of clad steels In the discussion that followed, questions were asked concerning methods used in manufacture that were not covered in the paper. As to cladding on both sides of a base metal, it was stated that the edges are protected by a weld bead. As to the necessity of a decarburization treatment of the base metal when nickel cladding is used, it was stated that decarburization is not necessary, but does usually exist at the surface of the base metal since rimmed steel is ordinarily used. The nickel is easily bonded to carbon steels.

The second paper, "Influence of Temperature on the Affinity of Sulphur for Copper, Manganese, and Iron," was read by D. T. Rogers, co-chairman, since the author, A. S. Skapski, was absent due to the blizzards while enroute. It was the consensus of opinion that the theme that copper interferes with desulphurization requires further

intensive investigation. Those who produce copper-bearing steels said that statistical correlations have failed to show that high sulphurs are a result of the influence of copper in the steel.

The Wednesday afternoon session was again devoted to Steelmaking. The Brower-Larsen paper, which was well-received, covered studies on production rates based on net heat values for various types of charges: (1) Hot metal and scrap in various percentages, (2) all cold charge and (3) duplex charge. Some of the variables influencing heat balance were described as relative oxidation by air or by ore, use of light or heavy scrap, carbon content at melt, use of oxygen blowing, and limestone charged.

The Chipman-Chang article, "Ionic Nature of Metallurgical Slags—Simple Oxide Systems," discussed chemical behavior of steelmaking slags from the viewpoint of their ionic constituents. This ionic conception is based on the Lewis electron theory of acids and bases, and the resulting slag-metal. slag-gas reactions were discussed. This was mainly a theoretical presentation by John Chipman.

Post and Luerssen in their paper, "Interaction of Liquid Steel with Ladle Refractories," discussed the sources of non-metallic inclusions in steel in the light of the chemical reactions between ladle refractories and hot metal, as opposed to inclusions produced by chemical reactions in the furnace, or in subsequent deoxidation. Data was presented on the effect of manganese and silicon contents of basic electric steels and the resulting cleanliness thereof. The paper was of considerable interest

as proved by lively discussion, during which some doubted the practicability of producing low manganese, high silicon grades of steel.

The paper, "Relative Deoxidizing Powers of Some Deoxidizers for Steel," by C. E. Sims, compared such commonly available deoxidizers as manganese, vanadium, calcium and silicon. Aluminum, zirconium, titanium and boron were also discussed and a theory of deoxidation expounded and compared with existing data. There was considerable discussion, with John Chipman objecting to several statements in the paper.

INSTITUTE OF METALS DIVISION

Phase Diagrams was the topic for the first session of the Institute of Metals Div. on Monday morning, with three papers covering the subject. A broad temperature range was represented by the alloy systems used—the low melting Pb-Sn system, the high temperature Pt-W alloys and the Au-Ag-Cu system, in between. Dr. M. B. Bever, of M.I.T., pinch-hitting for McMullin and Norton, gave a fine presentation of work on the Au-Ag-Cu system but the results were so clear-cut that little discussion developed. The work of Jaffe and Nielson on the Pt-W system involved more difficult techniques and many more questions were asked, centering on the method of preparation of the alloys and the interpretation of the microphotos. The main question was whether certain impurities which may have been present in the starting materials but probably eliminated during subsequent opera-

Metals Branch Luncheon in Fairmont Hotel. Looking for mermaids?

tion, might have caused a microstructure similar to those in which a liquid phase had been present.

The final paper showed how the measurement of electrical resistance could be used to determine a solidus temperature, although for the particular system used, Pb-Sn, it also gave excellent results for liquidus temperatures. The work was ably presented by Dr. Potter of Berkeley, Cal., in the absence of both Dr. Hultgren and S. A. Lever.

Grain Boundaries and Surfaces was the topic for the Monday afternoon session. The discussion that followed the papers suggests that there is beginning a period in which considerable attention and research effort will be devoted to energies and other characteristics associated with interfaces in solids. Up to now no reliable measurements had been made of either the surface or the interfacial energies of any solid. The first apparently reliable surface energy measurement was being presented at the Thursday morning session on Powder Metallurgy and measurements of interfacial energies are being undertaken by several newly devised techniques at several laboratories. Interfacial energies between solid phases depend not only on the nature of the phases but on their relative crystallographic orientation and on the orientation of the boundary between them.

Interfacial and surface energies are particularly important on the formation and behavior of thin films. These energies may cause the equilibrium temperatures and compositions in such films to differ markedly from those in massive specimens.

Thought is being given also to the changes in physical and chemical properties associated with equilibrium shifts at interfaces, such as grain boundaries and slip lines in solid metals. These shifts may simply cause the concentration of various elements in solid solution to be different near the interface than in the bulk of the metal, or they may lead to formation of new phases at the interface. Such changes appear to underlie stress-corrosion cracking, which may be intergranular or along slip lines, depending both on the nature of the alloy and on the degree of previous cold work (as well, no doubt, on the corrosive medium). The discussions at this session tied in closely with those at the Thursday sessions on Powder Metallurgy.

THREE POWDER METAL-LURGY SESSIONS

About 55 attended the first Powder Metallurgy Session Wednesday afternoon at which four papers were given. Pol DuWez (with Leo Zwell co-author) presented "Pressure Distribution in Compacting Metal Powders." John Wulff (with R. Kamm, and M. A. Steinburg as co-authors) presented "Lead Grid Study of Metal Powder Compaction." S. J. Sindeband read the paper, "Properties of Chromium Boride" while Dr. J. F. Norton read a paper that he had authored with A. L. Mowry on "Solubility Relationships of the Refractory Monocarbides."

Discussions were lively, among those taking part having been: Alexander Squire, Westinghouse Electric Corp.; J. J. Cordiano, Buel Metals Co.; Dr. Egon Orowan, who presented the Institute of Metals lecture; W. J. Kroll, Bureau of Mines; T. E. Norman, Climax Molybdenum Corp.; Mr. Day, Metal and Thermit Corp. and others.

At the Powder Metallurgy Seminar Thursday afternoon A. J. Shaler served as leader, presenting a comprehensive theory of the kinetics of the sintering process in single metals based in part on new experimental results. A lively discussion followed. An argument arose over Dr. Shaler's derivation of the forces of attraction between individual powder particles, disputed by Drs. Orowan and Kuscynski.

Dr. Shaler's theory of the change in pore size due to viscous flow under the influence of the forces of gas pressure and surface tension was disputed by Dr. F. N. Rhines, who said that lattice vacancies have a tendency to diffuse from smaller pores to larger ones, thereby increasing the average size of the pores, but decreasing the number of pores with time during the sintering process. Densification, according to Rhines, is due to diffusion of lattice vacancies to the surface of the contacts. Both Drs. Shaler and Rhines had experimental data to back up their theories, but further experiments will be necessary to resolve the differences between them.

It has been through the individual reports of the following that the overall report of the Metals Branch sessions of AIME, as herein published, were possible: T. D. Jones, W. S. Reid, H. R. Hanley, John D. Sullivan, A. A. Smith, Jr., G. H. Enzian, R. C. Madden, R. Beard, H. C. Sweet, E. R. Jette, J. D. Jaffe, Lee S. Busch, and F. V. Lenel.

SMELTS and SMILES

By Edgar Allen, Jr.

"I don't care what the sign says—we don't stock beer or whiskey!"

AMONG THE MANUFACTURERS:

Blast Furnace Support

The steel plant of the Compania de Acero del Pacifico, under construction at the Bay of Vincente, five miles from Concepcion, Chile, is on a site subject to severe earthquakes. How to construct the blast furnace to withstand seismic forces was one of the most im-

portant design problems as the Chilean earthquake experts, Prof. R. Flores and Senor E. Arze were not satisfied with the conventional blast furnace mantel support commonly used in the United States. F. E. Kling, chief engineer, H. A. Brassert & Co., designed the all-welded mantel support shown in the photograph, taken in the William B. Pollack Co. shop, Youngstown, Ohio.
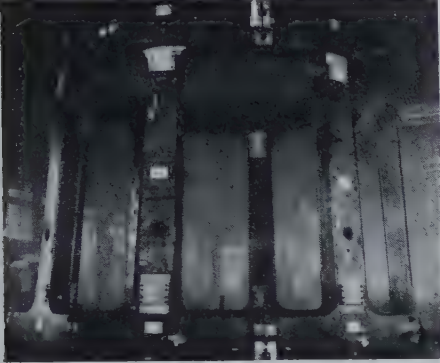
This design is a radical departure from usual American practice. The base, columns and mantel are made up of rectangular, hollow box-girder sections fabricated by welding from 1¼ in. plates. The design is calculated to give maximum stiffness to the whole structure so that it will adequately resist the bending, twisting and buckling forces likely to accompany an earthquake. The junctions of the base and mantel with the columns are flared out so as to transmit forces between adjoining parts without any excessive local concentration of stresses. The base, columns and mantel, after being welded together, form a rigid monolithic structure.

The new design is also considerably cheaper to fabricate and erect, with weight of 242,000 lb. as against 528,000 lb. conventionally. For a 12-tuyere, 20 ft. hearth furnace, the conventional design calls for 12 columns, while the new box-girder design permits the use of only eight, spaced alternately 40 deg. and 50 deg. apart, affording increased working space around the hearth and eliminating having tuyeres directly above the iron and cinder notches.

Speedy Drying Oven

A speed oven which is said to cut laboratory drying time in half, has been placed on the market by Harry W. Dietert Co., Detroit 4, Mich. Finding useful application in the chemical, industrial and other fields, it has a drying space 8 in. diam. and 6 in. high, with overall height of 29 in. Power requirements are 2800 watts at 115 or 230 volts. volts.

A motor driven fan forces filtered air past electric heating elements, with temperature thermostatically controlled between 150 and 350 F.

Manufacturers' Publications

To describe furnace equipment which enables users to harden steel precisely and to carburize and gas cyanide small loads, the Leeds & Northrup Co., 4907 Stenton Ave., Philadelphia 44, has published a 32-page fully-illustrated catalog: "Vapocarb-Hump—the Triple Control Method for Heat-Treatment of Steel."

———

"Instructions for Brazing Fittings to Pipe and Tubing with Easy-Flo and Sil-Fos" is the title of Bulletin 17 of Handy & Harman, 82 Fulton St., New York 7. The two main divisions pertain to preparation and brazing, with several line cuts adding to the understanding of the subject.

———

The "Development of the Metal Castings Industry," a book tracing the casting industry from its beginnings to the twentieth century, has been selected as one of the "50 books of the year" in a competition recently sponsored by the Institute of Graphic Arts. Over 10,000 examples of book design and production of the past year were con-

sidered by the judges. A second certificate of recognition for superior design and printing was awarded to the publishers, the American Foundrymen's Society, by the Society of Typographic Arts. Nearly 200 illustrations, gathered from all over the world, add to the book's attractiveness.

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The Babcock & Wilcox Co., 85 Liberty St., New York 6, has published a new booklet on refractory castables, plastics and mortars, describing the products, outlining their characteristics and indicating typical applications. Many of the products are suitable for temperatures as high as 3000 F and one, Kromecast, for as high as 3100 F. The book is intended for designers, builders and operators of all types of industrial furnaces.

———

A 4-page bulletin on the Dillon Multi-Low-Range Universal Tester has been issued by the manufacturer, W. C. Dillon & Co., Inc., 5410 W. Harrison St., Chicago 44. It contains a full description of the operation, with photographs of all parts.

Men of Industry

Dr. Willard D. Peterson has joined Arthur D. Little, Inc., Cambridge, Mass., consulting research and engineering organization. He was previously associate director of research and development at J. T. Baker Chemical Co. He will consult in the fields of process development and the general field of photographic materials and facsimile duplication, with particular emphasis on diazo-type reproduction. He received a PhD degree from Harvard University.

———

Admiral Ben Moreell, president, Jones & Laughlin Steel Corp., proposes a change in the Federal tax law to allow companies to write off the cost of new equipment more rapidly than they may now, a plan which would help the steel industry modernize faster than now possible. The present tax law, he says, doesn't take account of the rising price of equipment, that and plant cost having more than doubled. "We can't use yesterday's tools for today's work and be in business tomorrow," he says.

Book Reviews

tween theory and practice in the science of metals. The book is the first in a series of monographs in the science of metals sponsored by the Institute for the Study of Metals at Chicago. The origination of the series is a most welcome event and it is hoped that the forthcoming volumes will not deviate from the high standard of Dr. Zener's book and will keep up the truly scientific character of the publications.

Iron Powder Compacts

Powder Metallurgy. By Alexander Squire. Mapleton House, Brooklyn, N. Y. 1947. $8.

REVIEWED BY F. V. LENEL

THIS book is a collection of nine reports on investigations which were performed by Mr. Squire in the laboratories of Watertown Arsenal during the war. For security reasons the circulation of the reports was restricted during the war, but in 1947 the reports were declassified and reissued by the Office of Technical Services of the U. S. Department of Commerce. The publishers of the book reproduced the typewritten OTS reports by the photo offset process, put them in a cover, and gave them the title "Powder Metallurgy," although they are concerned with one quite specialized phase of power metallurgy, the application of the process to the production of ordnance components. The reports have obviously never been intended to be either an introduction or a survey of the entire field of powder metallurgy.

Except for the second report, which contains a critical survey of the application of powder metallurgy to ordnance design, all reports present the results of experimental investigations on iron powder compacts. The most important of these investigations, the 5th, 6th and 7th report of the book, have been presented by Mr. Squire before AIME and will be found in "Metals Technology" for April 1947 and in volume 171 of the "AIME Transactions" page 473 and page 485 under the titles "Iron-Graphite Powder Compacts" and "Density Relationships of Iron-Powder Compacts." Of the five remaining reports, two, namely the first and fourth, are extensions of the paper on Iron-graphite powder compacts and present data on specimens which were heat-treated by quenching and tempering.

Book Reviews

(Cont. from Page 30)

Two others, the third and the ninth, form an introduction and a supplement to the paper on density relationships. The third contains extensive data not only on tensile properties, but also on bend strength, shear strength and bend angle of iron-powder compact and their relation to the tensile properties. The ninth extends Squire's relationship between density and mechanical properties from iron-powder compacts which are merely compacted and sintered to compacts which are also repressed and resintered. The last report, which is in the 8th place in the book, records some data on the improvement in flow of iron powders by treating them with methyl chlorsilane vapor.

There have been all too few systematic investigations of the mechanical properties of iron-powder compacts and the results of Mr. Squire's careful, impartial, and extensive series of tests have been studied with great attention by those interested in the field. In view of their specialized topics they are of only limited interest to the general metallurgist. It appears that the publishers have sought to exploit the present great interest in powder metallurgy by giving the collection of the reports its rather misleading title and selling the book at a price which seems to be incommensurate to its length and its method of reproduction.

Engineering Societies Personnel Service, Inc.

New York—8 West 40th St., Zone 18.
Detroit—100 Farnsworth Ave.

San Francisco—57 Post St.
Chicago—84 East Randolph St., Zone 1

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In applying for positions advertised by the Service, the applicant agrees, if actually placed in a position through the Service as a result of these advertisements, to pay a placement fee in accordance with the rates as listed by the Service.

When making application for a position include six cents in stamps for forwarding application to the employer and for returning when necessary.

All replies should be addressed to the key numbers indicated and mailed to the New York Office.

A weekly bulletin of engineering positions open is available to members of the cooperating societies at a subscription of $3.50 per quarter or $12 per annum, payable in advance.

POSITIONS OPEN

RESEARCH PHYSICAL METALLURGIST, young, with Ph.D. in metallurgy, for a long term fundamental study in the non-ferrous field. Scope of work extends into relatively new and little explored regions where the opportunities for both scientific and technical contributions are good. For a man interested in physical metallurgy research the proposed work offers interesting and challenging possibilities. Position requires that the individual have a good fundamental and theoretical background combined with good experimental aptitude. Some experience in experimental work is necesary and applicant should be of the "research" type. Location, Connecticut. Y1889.

METALLURGISTS, 2, 23-35, B.S. in Metallurgy or Mining; some practical experience necessary for one of them. In lieu of experience, a graduate who specialized in ore-dressing problems would be acceptable for one of the jobs. Duties will be to conduct ore-dressing investigations (mainly flotation tests and microscopic examinations) in the research laboratories and supervising special tests in the concentrators. Must be single, or single status till housing is available. Salaries, $2700-$3900 a year. Location, South America. Y-798.

METALLURGISTS. (a) Metallurgist-Mill Foremen, experienced college graduates. Knowledge Spanish. Three year contract. Starting salary, $5000 a year plus bonus and living quarters. Single preferred; if married, single status for 6 months. Transportation paid. (b) Junior Metallurgist, graduate, with some experience in ore dressing and laboratory test work; single status. Standard 3 year contract; base starting salary $3000 a year plus bonus; knowledge Spanish desirable. Transportation furnished to Bolivia by air. Four weeks' vacation plus free living quarters.

PROCESS METALLURGIST for process development and semi-works production of metals by chemical or electro-furnace reduction. Write stating qualifications, experience and salary expected. Location, New Jersey. Y-1646.

RESEARCH METALLURGIST, 30-40, graduate, with non-ferrous smelting and refining experience, to supervise development of hydro-metallurgical pyro-metallurgical and electrolytic refining methods. Salary, $4200-$4800 a year. Location, northern New Jersey. Y-1926.

METALLURGIST OR METALLURGICAL ENGINEER, young, B.S. degree, to study metals and processes used in electron tube development and manufacture. Tungsten, molybdenum, nickel, nickel alloys, copper and stainless steel alloys are the principal metals involved. Principal processes are work with the joining of metals by brazing and welding techniques. Location, southern New Jersey. Y-2144(a).

TEACHING PERSONNEL in the field of metallurgy and metal processing. (a) Instructors, Doctor's degree or New York State Professional Engineer's license with experience in teaching and industry. Salary, $3000-$5400 a year. (b) Assistant Professor with Doctor's degree or New York State Professional Engineer's license and experience in teaching and industry. Salary, $3900-$6767 a year. (c) Lecturer, qualified to obtain Doctor's degree, or holding a P.E. license in other states entitling him to take examination in New York. Salary open. Location, New York, N. Y. Y-2215.

METALLURGIST, 25-35, must have had experience in the melting and processing of stainless steel, nickel, steel, nickel chrome alloys and other high temperature alloy. This is in connection with a research and development program. Salary, $4200-$4800 a year. Location, Michigan. D-4771.

MEN AVAILABLE

MILL SUPERINTENDENT-MILL METALLURGIST, 44, married, B.S. in Mining Engineering, registered Metallurgical Engineer. Wide experince as operator, superintendent and in original research in complex lead-zinc-gold-silver-copper, gold and non-sulphide copper silver. Seeks permanent connection with responsibility. Prefer southwestern U. S. A. or Mexico. M-416-475-E-6-San Francisco.

METALLURGICAL ENGINEER, B.S. in Metallurgical Engineering, 26, married. Six years' experience including two and one-half years ferrous welding research, one year magnesium and aluminum production and sales, two and one-half years college teaching in engineering. Desires research or teaching position in East. Available June. M-420.

PROFESSIONAL SERVICES

Erle Daveler receives Certification of Honorary Membership from William Wrather at the Annual Banquet.

Biggest Technical Program Marks First Annual Meeting on Coast

REPORTED BY LEWIS A. PARSONS

Now that the 77th Annual Meeting of the AIME, and the first held in San Francisco, is over, there are few left who have not been convinced that a successful meeting can be held outside New York. This meeting is memorable not only because the technical program was the biggest in AIME history, but also because of the outstanding success of the many social events arranged to entertain visiting members and guests. Long-remembered by the 2000 in attendance will be the Annual Banquet, the All-Institute Luncheon, the St. Valentine's Day Dinner Dance, the Stag Smoker, the various Division lunches and dinners, and the well-attended program of the Woman's Auxiliary.

The ladies, perhaps, should be mentioned first, for without their charm and beauty none of the Institute events could have been as pleasant as they turned out to be. Under chairmanship of Mrs. H. Robinson Plate, the Woman's Auxiliary arranged a full program of its own. Attendance was extremely heavy, about 300, which was believed to be an all-time record for the Auxiliary.

The 1949 meeting reached its high point in the Annual Banquet which attracted 1065 members and their guests to the colorful Garden Court of San Francisco's historic Palace Hotel. It was there that the incoming and outgoing officers of AIME, together with the distinguished award winners, were honored by their fellow members. Before the Banquet began, there were two receptions for those who were later to be seated in places of honor on the dais. The warmth of heart and general conviviality brought much gaiety to the otherwise formal affair.

Robert Gordon Sproul, president of the University of California, gave an inspiring address stressing the great moral strength of the American way of life. Seating was arranged in tables of ten, each table graced by large

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Attendance at 1949 Annual Meeting Compared to 1948

	1949 San Francisco	1948 New York
Men's registration.	1820	1804
Women's registration	338	226
Annual Banquet..	1065	1125
Dinner-Smoker ..	462	845
All-Institute Luncheon	740	545
Informal Dance ..	575	522

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sprays of western flowers. As a memento of the event, every lady present received a souvenir gold pan commemorating the California Gold Rush of 1849. Dancing began when the formal business of the evening was concluded, and many remained until two o'clock in the morning.

The tremendous success of the entire social program was presaged on the first day of the meeting, when an overflow crowd gathered at the Fairmont Hotel to hear an address by Governor Earl Warren of California at the annual All-Institute Luncheon. Dr. Wrather introduced the guests at the speaker's table after which he presented William Wallace Mein, Jr., Chairman of the San Francisco Section and also of the Annual Meeting Committee, with a gold watch fob from the San Francisco Section in appreciation for his work in organizing the Annual Meeting. Next on the agenda was the announcement of winners of the Student Prize Paper Contest. W. E. Ellis, the only winner in attendance, received his award.

Governor Warren, in discussing the early history of California gold mining, said that the City of San Francisco was built by the gold miners and that in February of 1849 there were fewer women in San Francisco

Dancing after the formal banquet was fun and lasted until the wee small hours.

than presently attending the AIME meeting. To the amusement of everyone, he read an editorial from the *Engineering and Mining Journal*, commenting on a Regional Meeting held in San Francisco fifty years ago, which suggested that the pleasures of the meeting interfered with business and that these meetings might better be discontinued. The present-day AIME member seems to be able to take his technical sessions, hangovers notwithstanding.

That same evening, 575 enjoyed a St. Valentine's Day buffet dinner dance in the newly decorated Peacock Court at the Mark Hopkins Hotel. Music was by Ray Hackett's orchestra —a point of particular interest to mining men since Hackett got his start at one of the nation's well-known mining schools, the University of Nevada. The food, in the words of one happy delegate, was "beautiful to look at and wonderful to eat." California wines were placed on every table, and many Easterners became acquainted for the first time with the glorious bouquets developed by the vintners of the West. Excellent formal entertainment was provided in the main room during the course of the evening, but those in the back room, to whom this was not visible without leaving their tables, took things in their own hands. A group of well-known petroleum production men and their wives, arms entwined, stood around a table of long-haired beneficiation researchers and harmonized

to the tune of "I Been Working on the Railroad."

Those who were lucky enough to attend are still talking about the Stag Smoker which was held in the San Francisco Commercial Club on the evening of Feb. 15. Professional entertainment was drawn from leading night clubs in the San Francisco area, but it took a pair of comparative amateurs to steal the show. The amateurs, Rip Borden and Phil Bradley, Jr., introduced a new scheme for national taxation which many delegates thought had excellent possibilities for development. So well received were their suggestions relative to Uncle Sam's excise taxes that they provided an encore in which the functions of the Institute's Board of Directors were explored.

On the same evening, the Petroleum Division held its Annual Dinner at the Fairmont Hotel. Reese Taylor, president of the Union Oil Co. of California, delivered an address entitled "The Greeks Had a Word for It." Petroleum Division Certificates of Service were presented to F. Julius Fohs and J. B. Umpleby. The Red Room, where the dinner was held, was filled to overflowing. Present, as indicated when called upon to take a bow, were many former chairmen of the Division and Institute officers, among the latter Directors Alford, Bowles, Millikan, Schumacher, and Suman. At the conclusion of the dinner Irwin W. Alcorn, Division Chairman, who presided, turned the gavel over to Lloyd

E. Elkins, incoming Chairman for 1949.

In addition to the many Institute-sponsored affairs were numerous private cocktail parties. Notable among these was a function hosted by Dr. and Mrs. Frank Girard, Mr. and Mrs. Worthen Bradley, Mr. and Mrs. James Parks Bradley, and Mr. and Mrs. John D. Bradley, in the Girard home in Pacific Heights.

Section Delegates from forty Local Sections gathered on Monday for an all-day discussion of Institute affairs and the relation of the AIME to its members. The main problem discussed was the Institute deficit and the possibility of retiring it by raising dues. This situation was thoroughly aired during the entire morning meeting and during most of the afternoon. After due deliberation, the Section Delegates voted to recommend to the Board that, because of the serious financial plight of the Institute, appropriate steps should be taken to increase the annual dues of Members and Associate Members from $15 to $20, and of Junior Members from $10 to $12, effective for 1950 and for two years thereafter; further, that a referendum be taken in 1952 as to the dues for succeeding years in light of the financial position of the Institute at that time. It should be noted that "appropriate steps" will include a referendum of the members, as provided by the bylaws.

Among other important matters discussed was the proposal to hold fewer and longer Board meetings which would convene at various convenient points around the country. This would increase the importance of each meeting and increase Director attendance. Routine matters could be dealt with by the Executive and Finance Committees at monthly meetings, subject to approval later by the entire Board. The Delegates went on record in favor of this proposal.

Before adjournment the Delegates voted to express their appreciation to the San Francisco Section for their hospitality at this Annual Meeting and to thank Dr. Wrather for his outstanding service to the Institute as President in the difficult year just passed.

technical program

The technical program was bigger than ever before, being comprised of some 60 sessions covering all phases of the mineral industries. The unity and purpose of the Institute meetings were best expressed by the number of joint sessions between various Divisions. Outstanding examples of this joint interest were such sessions as the Minerals Beneficiation Division and the Iron and Steel Division on "Pyrolysis and Agglomeration"; and Extractive Metallurgy, Industrial Minerals. and Iron and Steel Divisions on "Titanium."

Educators convened on Sunday on the beautiful campus of the University of California in Berkeley for afternoon and evening sessions which were interrupted only by cocktails and a buffet supper. The other Divisions and Committees of the Institute began their technical programs on Monday, many lasting for the full four days. The Society of Economic Geologists met jointly on Tuesday and Wednesday with the Institute's Mining Geology Committee. As usual, Division and Committee luncheons served the joint purpose of satisfying the inner man and conducting the annual business meeting of the group. The luxurious dining rooms of the Fairmont, Mark Hopkins, Clift, and Bellevue Hotels provided attractive settings for these affairs. Numerous motion pictures, mostly through the courtesy of the Bureau of Mines, added interest to the technical sessions.

Affairs of the Metals Branch of the AIME were conspicuous in the program. There were 28 sessions, including technical papers, luncheons, and lectures. The number of papers was over 65 and usually the formal papers were followed by lively discussions. Nor were those who discussed papers shy in taking exception to theories presented.

One of the main events was the Institute of Metals Division lecture by Egon Orowan, Cavendish Laboratory, Cambridge, England, on "Structure of the Cold-worked Metal." Equally well-received was the Howe Memorial Lecture on "What Is Metallurgy?" by John Chipman, head, department of metallurgy, Massachusetts Institute of Technology. In place of the usual Institute of Metals Division dinner and the Iron and Steel Division luncheon, a successful Metals Branch luncheon attended by an even 100 inaugurated the formation of the Metals Branch.

The technical program of the Petroleum Division began on Monday afternoon with a review of foreign and domestic production. On Tuesday morning there were three papers on economics subjects and the Wednesday morning and afternoon sessions were devoted to petroleum technology. Mr. Elkins presided at the open session of the Executive Committee for 1949 on Thursday morning.

Detailed reports of the various Division and Committee technical sessions appear in Section 1 of the appropriate Branch journals.

An airplane trip over San Francisco was conducted on Wednesday and Thursday through the courtesy of Pan American Airways. V. L. Vanderhoof, of Stanford University, accompanied the trips and pointed out sights of cultural and industrial importance in addition to giving an interesting commentary on them.

Olaf P. Jenkins took about 23 in a Greyhound bus on a field trip to see the sights and geology around the Bay area. The day was bright and sunny and so everyone was in good spirits as the trip started across the Bay Bridge and toured the Berkeley Hills returning to Richmond on the ferry. An excellent luncheon was enjoyed at the Hamilton House in Fairfax. The party continued to Olema on the San Andreas fault and finally returned to San Francisco across the Golden Gate Bridge. Another trip was led by Edgar Bailey to study the geology of the New Almaden quicksilver area. Both of these trips were enjoyed by all who participated. About a dozen people signed up for the post-meeting trip to Hawaii which was a 6 to 10 day tour of the interesting points of the Islands. It will be a long time, if ever, before the many enjoyable experiences of the 1949 meeting in San Francisco are forgotten.

The general committee, headed by William Wallace Mein, Jr., the finance and banquet committees headed by Walter L. Penick, the entertainment and hospitality committee headed by Worthen Bradley, the reception committee headed by Richard D. Moody, the dinner-dance committee headed by P. R. Bradley, Jr., the stag smoker committee headed by Herbert A. Sawin, and the All-Institute luncheon committee headed by George H. Playter worked hard to make every event a success.

The San Francisco Section and the Institute as a whole acknowledge gratefully the contributions which so greatly helped in making this meeting possible. Among the contributors were:

Allis-Chalmers Manufacturing Co., American Brake Shoe Co., American Cyanamid Co., American Forge Co., American Rubber Manufacturing Co., American Smelting and Refining Co., Apache Powder Co.

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Quaker Pacific Rubber Co.

Shell Oil Co., Sonoma Quicksilver Mines, Inc., Sperry-Sun Well Surveying Co., Standard Oil Co. of California, Stephens-Adamson Mfg. Co.

Taylor-Wharton Iron and Steel Co., Tide Water Associated Oil Co., Timken Roller Bearing Co., Thurman Gold Dredging Co., Traylor Engineering and Manufacturing Co., Tyler Co., W. S. Union Pacific Coal Co., Utah Construction Co.

Western Precipitation Corp., Western Machinery Co., Westinghouse Electric Corp., Wildberg Bros. Smelting and Refining Co.

Yuba Manufacturing Co.

San Francisco drew a crowd for the Annual Meeting; here members register, meet old friends, and make new ones.

Seen at the Annual Meeting

But on Friday, before the clans gathered, some of the men responsible for the meeting's success attended a kick off luncheon.

With the meeting in full swing, Alice Fischer, only feminine metallurgist registered, meets President Young.

All-Institute luncheon fare was excellent (left) with Governor Warren (above) as pièce de résistance. L. E. Young and William Wrather are seated on either side.

Bain, McLaughlin, Fischer, and Page discuss atomic mineral deposits; (below) R. F. Davis speaks on petroleum refining at an MIED session, flanked by G. C. Gester and E. DeGolyer, moderator.

A Don Loper original of imported lace embroidered in an overall fern pattern with silver threads modeled during the Woman's Auxiliary fashion show; lovely, isn't it.

Robert L. Hoss receives the Alfred Noble prize from President Wrather. (Below) James Boyd, E. H. Robie, and Earl Warren chat at the All-Institute luncheon.

Dancing brings the Banquet to a pleasant close. It also marked the end of the formal social functions, but not the end of gatherings of friends in lobbies and corridors, and sightseeing in San Francisco. Thanks are certainly due to every one concerned with making the meeting a success.

Controversy on Mineral Supplies
Marks Mineral Economics Session

O. P. Jenkins, W. T. Hannum, and Governor Warren talk over mineral supplies as W. E. Wrather smiles on the gathering.

REPORTED BY JOSEPH T. SINGEWALD, JR.

A national mineral policy symposium comprised four papers covering a survey of domestic deficiencies and potential foreign sources by Alan M. Bateman, a consideration of critical factors affecting the domestic mining industry by Otto Herres, Jr., a review of progress in stock piling by Richard J. Lund, and discussion of the role of government in a national mineral policy by Donald H. McLaughlin. Elmer W. Pehrson and Charles H. Behre, Jr., served as chairman. Though replete with fruitful thought, the symposium resulted in no definitive solution of the complex problems of to what degree and how and when our domestic resources should be drawn upon and to what degree our domestic resources should be conserved by drawing on foreign supplies. The incompatibility of maintaining a strong domestic mining industry and not depleting our reserves presented a baffling problem.

Bateman's paper was presented by Mr. Pehrson. The war demands increased the former dozen strategic minerals to five dozen, of which 27 came only from foreign countries. Our own demand for many of them exceeded the existing world supply. The postwar demand has remained at the wartime level. The author is more optimistic over our mineral resources than the estimates in "The Mineral Resources of the United States," but emphasized the urgent need for the United States to become more internationally minded in providing the mineral needs of the future. Realignment of the sources from which we can supply our deficiencies due to developments in the international situation were described, including the dropping of the "iron curtain," which has either shut off or made precarious some of our most important sources of the past. Thus private industry alone can no longer be relied upon to assure the United States adequate mineral supplies from abroad, but must be supported through diplomatic channels. H. DeWitt Smith cited wasted war effort to supply our needs of such metals as manganese from domestic sources to the neglect of adequate foreign sources.

Mr. Herres pointed out that our domestic mining industry is not as strong as the record 1948 dollar volume might suggest, because we are operating under both a peacetime and a wartime economy determined by political interests that are diluting our dollars. Weakening factors are: higher wages not compensated for by added production, high taxes that destroy venture capital, removal of tariff protection, and neglect of the mining industry by the planners who are determined to support many other things by government subsidy programs. He warned that we should heed the lesson of Europe, which amassed great wealth by sel'ing goods to all the world only to waste its riches and resources in the devastation of war, by preserving our economic strength. Arthur Notman advocated conserving our limited resources and meeting current needs from the resources of our potential enemies, and Olaf Jenkins stressed the need to preserve stock piles for national defense instead of redistributing them as the threat of war decreases.

Richard Lund and Otto Herres at the symposium on national mineral policies.

Morris Muskat brings home a point at a MIED session. Also at the speaker's table are R. F. Davis, E. DeGolyer, A. C. Rubel, and C. A. Heiland.

Mr. Lund outlined the history of stock piling, the need for which was recognized during World War I and, although urged by the experts, was neglected during the 20's and 30's. Substantial progress was again made during World War II, but the lessons of that war were again forgotten, and sizable stocks of strategic materials were quickly legislated into peacetime consumption. The Berlin crisis forced a belated recognition that the stock pile is a high priority claimant. Stock piling was started over again so that by the end of 1948 all available funds had been spent or committed. Stock piling should not be restricted to foreign sources, but should include utilizing most economically low-grade domestic deposits. It was pointed out that in a future emergency, power will be a severe bottleneck, and it should

be stored by stock piling metals rather than ores. Philip R. Bradley, Jr., advocated the development of self-sufficiency through the encouragement of a wide search for mineral deposits under favorable government policy rather than through the short-sighted policy of government subsidies. W. D. Johnston, Jr., cited the newly established Brazil-United States Technical Commission which is planning the development of vast iron and manganese resources in Brazil by private capital.

Dr. McLaughlin advocated a national mineral policy of free enterprise under reasonable control. He regarded subsidies as undesirable, but needed if profits are sucked by taxes to be redistributed according to bureaucratic social control. A guaranteed price would stimulate private enterprise at home, and government

support is needed to increase foreign supplies. Both tax relief and financial aid cannot be had at the same time. He hoped that money and man power will not be wasted again, however, in searches for materials which we don't have. Though pleading for economy in government expenditures, he recognized the value of research and regional survey by the U. S. Geological Survey and the Bureau of Mines. Cooperation of government and industry in discovery during the war was approved, but the final steps of development should be left to industry. Ira Joralemon and Arthur Notman both endorsed his views. Though competitive free enterprise was accepted as the soundest national mineral policy a heavily-taxed mining industry was bound to lean to some extent on government aid.

Educators Discuss Effects of Research

on Education Trends   REPORTED BY J. D. FORRESTER

Under the general leadership of its Chairman, Curtis L. Wilson, the Mineral Industry Education Division held three sessions in San Francisco and Berkeley during the 1949 Annual Meeting. Following the usual custom of meetings which are held by the Division, the first session began at 2:30 Sunday afternoon, Feb. 13, in the Hearst Mining Building of the University of California, Berkeley, and

continued into Sunday evening, after cocktails at the Claremont Hotel and an excellent buffet supper at the Men's Faculty Club. The second and third sessions were comprised, respectively, of a technical program on Monday morning and a business meeting luncheon on Tuesday. Attendance at the different meetings was good and the interest maintained throughout the sessions was extraordinary. Eighty-five

were present at the Sunday meeting, 40 members attended the Monday technical session, and 18 were present at the luncheon.

The general theme adopted for the Sunday sessions, which served as a guide for the formal speeches, was "Mineral Engineering Education of the Future in the Light of Present Day Research Problems." Several outstandingly informative talks were of-

fered on various aspects of the subject. David R. Mitchell read Dr. Lawall's paper, Fred C. Bond offered an analysis of F. T. Agthe's manuscript, and R. F. Davis read Dr. Egloff's paper. All other papers scheduled for the Sunday program were presented by their respective authors. As evidence of the capacity of the speakers and of the timeliness of the general topic, each of the contributions led to extensive discussion by the assembled members.

J. R. Van Pelt and Everette De-Golyer served, respectively, as moderators of the Sunday afternoon and evening sessions. They stressed the advancement made by industry through academic and industrial research and cited the importance of

fundamental experimentation as demonstrated by the tone and caliber of the talks offered by the speakers of the forum.

The Monday morning program was held in the Mark Hopkins Hotel in San Francisco. Analyses were offered of curricula in various phases of mining and metallurgy, and statistical data of graduate and undergraduate enrollments in schools of the mineral industry were presented. Harry E. Nold's paper on registration of engineers was given by Dean Wilson and William B. Plank's and Edward Martinez's contribution was read by Robert T. Gallagher. All other papers were delivered by the respective authors.

At the luncheon-business meeting of

the Division held in the Clift Hotel, it was announced, by Dean Wilson, that Messrs. Gallagher, Thomas L. Joseph, and Ben H. Parker had been elected to the Executive Committee of the Division. They will serve until February 1952. Other officers of the Mineral Industry Education Division will serve during 1948-49. In closing the business meeting Dean Wilson expressed his appreciation to all participants in the programs of the Division. He gave special thanks to Dr. Gallagher for his splendid service as Program Chairman and to Lester C. Uren and Carlton D. Hulin for their joint efforts as hosts of the Sunday meetings held on the University of California campus.

Students Question Industry on Prospects

REPORTED BY JOHN V. BEALL

Mineral industry students gathered, about seventy strong, from four different colleges at the annual meeting in San Francisco for the second in what is hoped will be a series of student forums at AIME meetings. The series started auspiciously at the El Paso Regional Meeting and continued in San Francisco in what would have been a rapid fire question and answer session if the answers were as easy to give as the questions were to ask. Schools represented were the University of California, Stanford, and the Universities of Nevada and Arizona. Jay Carpenter, of the University of Nevada, was moderator and was supported by "elders" (we don't know who thought up this term but everybody got a kick out of it) L. E. Young, representing coal; James A. Barr, Sr., industrial minerals; James A. Barr, Jr., research; Barney Haffner, metal mining; Richard Moody, manufacturing; Harold J. Clark, petroleum; and Ira Joralemon, mining geology.

supply jobs open

Professor Carpenter was introduced by Lawrence Wright, who, incidentally, can moderate for us anytime. Jay

quickly found out who his audience was by a fast poll which elicited the following facts: most of the students were from the University of California; roughly 25 were miners, 25 petroleum engineers, the rest being split between geology and metallurgy; 50 per cent married; 70 per cent veterans; and lo! one lovely lady miner. Without further ado, Mr. Moody was given the floor to describe the training program of Allis-Chalmers which he said was not unlike those of Ingersoll Rand, General Electric, and Westinghouse. In brief, the course is 18 months long, with the applicant going to Milwaukee where he is processed through the shop, design, research, and sales departments during that period. An aptitude test is given to help him decide which of the fields he would like to follow; design, research, or sales. Starting pay is around $250 and is raised to $270 by the end of the course. While in training, a man can go on and take a master's degree. Mr. Moody pointed out that sales work was engineering because equipment is sold on its engineering merits, its ability to do a particular job; and therefore salesmen must be able to help customers

with their engineering problems. These companies hire all types of engineers. Our lady miner, Mrs. L. R. Miller, asked if the course was open to women. Mr. Moody said that they had never had a woman take the course but he didn't see why one couldn't. Mr. Barr, Sr., volunteered that he had a woman chief of party and a chemist, both of whom had gotten along fine.

opportunities in large vs. small companies

The question was raised from the floor as to whether it was better for a graduate beginner to work for a big company or a small one. Barr, Sr., commented on his experience in starting with a small company, but moving shortly afterward to International Minerals and Chemical with which organization he has been ever since. His feeling was that a young man got more experience with a large company. On the other hand Mr. Barr, Jr., had moved 25 times in his early days with the idea of seeing as much as he possibly could. He thought this was a good procedure if you had a wife who could take this kind of treatment. He is now a research man

for Armour. Mr. Haffner, who is general manager for Bunker Hill & Sullivan, thought that a man should go with a large company where he can learn something and then size up the situation as opportunities for transfer occur. Mr. Haffner is an exponent of the young mining engineer starting in production. Mr. Joralemon was of the opposite inclination. In a small company you learn more as you have to do a little bit of everything.

Dr. Young, who is a coal mining consultant as well as President of the AIME, outlined the procedure followed by a progressive coal company with a recent graduate. The young man is put into production work, either being shifted through various production jobs, or put on time study, or safety. At the end of three years he should apply for a qualifying certificate from the state in which he is employed. Starting salaries are set equal to the rate paid by any other industry in the area. Dr. Young followed a policy, when he was managing, of raising the man $25 every six months if he was worth it or firing him if he couldn't make the grade. He was of the opinion that large companies had a better organized training program than small companies. Putting a man in the surveying department of a coal company was a mistake in Dr. Young's opinion as the work of that department has to do chiefly with reserves and property lines and requires an intimate knowledge of the company's holdings. Also there would not be an opportunity to learn production work in this department. Dr. Young explained that a young man must broaden his knowledge after graduation on his own initiative. He should study economics, labor relations, and government in order to build a background suitable for promotion to the higher echelons of company organization.

foreign work discussed

On the request of the students, the question of the advantages or disadvantages of foreign work were discussed by the "elders." Mr. Barr, Sr., said that it was a question of whether you wanted to stay abroad or not, as the opportunities for advancement were good if you remained abroad but on the other hand it was hard to get a comparable job in the States after you had been foreign for a while. Professor Carpenter opined that to get into pioneering you had to go abroad. The biggest problem in this sort of work, he maintained, was the frequently adverse living conditions. However, in his opinion, one did not lose contact with people at home. In a reminiscent frame of mind, Jay went on to say that students didn't go leasing these days as they did in the old days. Until you had gone bust on a lease you hadn't cut your teeth in the mining profession. This brought a chuckle from the "elders." There was a decided note of nostalgia for the romance of mining in the old days in this soliloquy. Jim Head, a Chile Exploration man, was asked for his opinion on foreign work. Jim said that he wouldn't take anything in exchange for his years abroad and the contacts he made were the pleasantest of his life. In explanation to the students of the difficulties in taking one's wife abroad which is prevalent with many companies, he stated that housing was short and the mining companies were working to remedy this situation. As a word of caution, Mr. Head said that there was no quick road to the top in the mining industry.

advanced degrees
depend on individual

The question of whether a man should work for an advanced degree or not was raised and Dr. Young replied that if the man was going into production work, he should get some experience first. Joseph T. Singewald, Jr., professor of economic geology at Johns Hopkins, suggested that field work was essential for a student who wished to take an advanced degree in geology. However, this work could be done during the summer with the USGS or with operating companies while the man was completing his course.

Opportunities for geologists in exploration were outlined in response to questions raised by the students.

Mr. Joralemon said that they were excellent, particularly in foreign exploration, as so few men are willing to go. He pointed out that a good man can make just as big a name for himself abroad as by working at home. Mr. Haffner said that they used geologists at Bunker Hill and that the attitude of operators toward geologists has changed in recent years. Formerly the operator thought the geologist was only good for telling how the ore got there after the operator mined it. Mr. Haffner went on to say that most mines now used geologists to aid in development and that at his mine $300 was the starting salary.

older students
not at disadvantage

Since most of the students were veterans of World War II, their average age was higher than in normal years. Hence the question was raised as to whether these older men were at a disadvantage after graduation. Professor Carpenter answered this pertinent question by assuring them that their wartime experience in human relations and handling men more than made up for their late start in industry.

S. S. Arentz, general superintendent at Pioche for the Combined Metals Reduction Co., wound up the meeting with a few amusing anecdotes from his experience as a mine operator which pointed up the fact that understanding the miners was the operator's most important job and the best way to learn to do this was to work as a miner.

Scholarships from Coal Industry

Scholarship awarding has been added to the ever-growing activities of the bituminous coal industry. Various coal companies and associations who want to improve mining community life and create a pool of available engineering personnel for the bituminous coal industry are currently providing 94 college scholarships. Among the seventeen organizations offering the scholarships are the Central Appalachian Section of AIME, with three, and the Coal Division of AIME, with two.

Jane Rees models an embroidered lace evening dress at the fashion show sponsored by the Woman's Auxiliary.

Woman's Auxiliary Enjoys San Francisco's Hospitality and Social Events

REPORTED BY MRS. E. H. ROBIE

Setting a standard of hospitality that will be difficult to equal, the committees of the Woman's Auxiliary under the efficient direction of Mrs. H. Robinson Plate, with the generous financial and personal support of the San Francisco Section, planned and carried out a successful program of entertainment for the ladies at the Annual Meeting of the AIME.

On Sunday evening, Feb. 13, the first social gathering, a cocktail party in the spacious home of Dr. and Mrs. Frank Girard, gave over 400 members a pleasant opportunity to meet old friends.

Monday morning 288 women registered in the lobby of the Fairmont Hotel. Most of the ladies decided not to miss any of the interesting affairs scheduled for their entertainment.

Governor Warren of California held the attention of those who attended the All-Institute Luncheon on Monday. It is easy to understand why he is the choice of both Democrats and Republicans in his home state.

Monday evening the Informal Dinner Dance in the artistic Peacock Court of the Mark Hopkins Hotel was a great success. Guests were seated at small tables lighted by hurricane lamps and served themselves at the buffet supper placed at one side of the room. The food was so artistically prepared and arranged that it was an added decorative feature. Amusing entertainers appeared during the evening and a fine orchestra made dancing a pleasure.

The Annual Meeting of the Auxiliary on Tuesday morning at the Mark Hopkins Hotel, presided over by the president, Mrs. Thorne E. Lloyd, was notable for its brief informative section reports under the direction of Mrs. H. A. Prosser. Lewis E. Young, President of AIME for 1949, addressed the meeting briefly, emphasizing the value of the work of the Auxiliary especially in the field of educational scholarships. A number of young, brilliant men whom he has known have been able, through these scholarships, to prepare for engineering careers.

Mrs. H. W. Hardinge, Chairman of the Chest Committee, reported briefly on the National project, the rehabilitation work under Howard Rusk at the New York Hospital.

Luncheon at the Top of the Mark followed. From the glass enclosed observation tower, the harbor, the Oakland and Golden Gate Bridges, and much of San Francisco can be viewed. It is a favorite spot at the cocktail hour when the colors of the setting sun fade and in the twilight that follows the twinkling lights of the city give a jeweled outline to bridges, buildings, and landscape below.

After luncheon we were driven by bus and private cars to tea at the home of Mr. and Mrs. W. W. Mein. This beautiful residence, set in the hills on the peninsula beyond San Mateo, was designed by Sir Herbert Baker the architect who planned the home of Cecil Rhodes in South Africa.

On Wednesday Mrs. Newell Alford conducted an interesting round table discussion in the Bonanza Room at the Mark Hopkins Hotel. A number of helpful ideas were brought out. Emphasis on the personal approach in Auxiliary affairs was stressed. Some membership chairmen telephone prospective members and many write personal letters. It was suggested that new members be appointed to working committees, also that older members make a special effort to talk to new members at meetings and so make them feel like part of the group. The round table was followed by a luncheon fashion show at the St. Francis Yacht Club where attractive mod-

els displayed the smart clothes so well that many guests hurried to The White House to get first choice of the well designed costumes. Buses and cars carried the guests back to San Francisco past the Yacht Basin to the Fairmont Hotel, a distance of five miles.

The Palace Hotel was the setting for the Annual Banquet Wednesday evening where a delicious dinner was served. President Wrather presented the special awards and medals and greeted Dr. Young as President of AIME for 1949. The ladies were presented with attractive silver pins in the shape of a miniature California gold pan, the gift of the contributors to the Annual Meeting entertainment fund. This favor appropriately marked the centennial celebration of the discovery of gold in California. Robert G. Sproul, president of the University of California, made the address of the evening. Dancing followed the formal ceremonies and many stayed until one a.m. to enjoy the last strains of the orchestra.

Although the banquet marked the end of formal social functions the corridors and lobbies of the hotels were filled with friends on Thursday and Friday. These last two days afforded time for trips to the attractive shops, to Chinatown, Fisherman's Wharf, and to the homes of friends. A number of fortunate women accompanied their husbands by plane to Honolulu.

Those who traveled by train through the snow blocked area of the middle west will recall the difficulties in reaching the Golden State of California in 1949. Many will remember the superb views of San Francisco, the cable cars, the cosmopolitan atmosphere of gayety, Chinatown, the fog that often blanketed the streets and muted the sounds of whistles from the harbor, all of which made their unique contribution to the setting for this successful Annual Meeting.

Woman's Auxiliary
Girls Loan Fund Successful

A total of twelve girls have been put through school in the past eighteen years by the Girls Activities Loan Fund of the Women's Auxiliary, New York Section, AIME, and yet the original gift of $5000 remains untouched. The fund has $250 a year on hand to enable daughters of anyone, living or dead, associated with mining or metallurgy, to obtain a practical education which will prepare them to earn a livelihood. Recipients agree to repay one-half of the loan, and thus far eight of the twelve girls have done so. Expert management has enabled the ladies to pay out nearly $5000, and yet keep the original gift in the bank, in the form of stock. The New York Section's Women's Auxiliary will be glad to answer queries, and receive suggestions as to possible recipients.

Calendar of Coming Meetings

APRIL
1 Columbia Section, AIME.
4 Boston Section, AIME.
5-6 Metal Powder Assn., 5th annual meeting and exhibit, Drake Hotel, Chicago.
6 Chicago Section, AIME. Continuous casting at B&W Tube Co.
6-10 AIChE, regional meeting, Los Angeles.
7 Reno Branch, Nevada Section, AIME.
11 Mid-Continent Section, AIME.
11-14 National Assn. of Corrosion Engineers, 5th Annual Conference and Exhibition, Netherland-Plaza, Cincinnati.
11-15 Western Metal Congress & Exposition, Los Angeles, Calif., AIME and ASM, etc.
11-12 American Zinc Institute, annual meeting, Hotel Statler, St. Louis.
12 East Texas Section, AIME.
13 El Paso Metals Section, AIME.
13 San Francisco Section, AIME.
13 Southwestern New Mexico Section, AIME.
15 Oregon Section, AIME.
18 Detroit Section, AIME. W. L. Grube on the electron microscope.
18-20 Midwest Power Conference, Sherman Hotel, Chicago.
18-20 Open Hearth Conference, and Blast Furnace, Coke Oven and Raw Materials Conference, Palmer House, Chicago.
19 Gulf Coast Section, AIME.
19 Washington, D. C., Section, AIME.
19-21 AIEE, Southwest district meeting, Baker Hotel, Dallas.
20 Southwest Texas Section, AIME.
20-23 ASCE, spring meeting, Oklahoma City.
21 Carlsbad Potash Section, AIME.
21 North Pacific Section, AIME.
21 Utah Section, AIME.
22-23 New England Institute of Metals Division Regional Meeting, Hotel Sheraton, Springfield, Mass.
22-23 Engineers' Day, Colorado School of Mines, Golden.
24-28 American Ceramic Society, national meeting, Netherland-Plaza, Cincinnati, Ohio.
25-27 Canadian Institute of Mining and Metallurgy, annual meeting, Windsor Hotel, Montreal.
25 Alaska Section, AIME.
26 Montana Section, AIME.

MAY
2-4 ASME spring meeting, New London, Conn.
2-5 American Foundrymen's Society, 53rd annual meeting, St. Louis.
6-7 American Institute of Chemists, annual meeting, Chicago.
8-12 AICE, Tulsa, Oklahoma.
9-12 American Mining Congress, coal convention and exposition, Public Auditorium, Cleveland.
11-13 Engineering Institute of Canada annual meeting with International Management Congress hemisphere meeting, Chateau Frontenac, Quebec.
14 Northwest Industrial Minerals Conference under auspices of Columbia Section, AIME, Spokane.
May 16–June 3 U.N. Scientific Conference on Conservation and Utilization of Resources, New York.
25 Iron and Steel Division, AIME, annual May dinner, Engineers Club, New York City.
25-26 American Iron and Steel Institute, general meeting, New York City.

JUNE
16 Engineering Foundation, 29 W. 39 St., New York City.
June 27-July 1 ASTM, 52nd annual meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.
20-22 American Society of Heating and Ventilating Engineers, semi-annual meeting, Minneapolis, Minn.
20-24 AIEE, summer general meeting, New Ocean House, Swampscott, Mass.

JULY
9-23 Fourth Empire Mining and Metallurgical Congress, Great Britain.
13-15 American Society of Civil Engineers, summer convention, Mexico City.
15-24 Pan-American Engineering Congress, Rio de Janeiro.

AUGUST
23-26 AIEE Pacific general meeting, Fairmont Hotel, San Francisco.

SEPTEMBER
25-28 Regional Meeting, AIME, Neil House, Columbus, Ohio.
25-28 American Mining Congress, Western fall meeting, Spokane.
29-Oct. 1 Colorado School of Mines, 75th anniversary celebration.
Sept. 30-Oct. 1 Southern Ohio Section of Open Hearth Committee, AIME, fall meeting, Deshler-Wallick Hotel, Columbus.

OCTOBER
5-7 Petroleum Branch, AIME, fall meeting, Plaza Hotel, San Antonio, Texas.
17-19 Institute of Metals Division, AIME, fall meeting, Allerton Hotel, Cleveland.
17-23 AIEE, 1949 Mid-West meeting, Netherlands-Plaza, Cincinnati.
28 Pittsburgh Section of Open Hearth Committee and Pittsburgh Section, AIME, annual fall meeting, William Penn Hotel, Pittsburgh.

NOVEMBER
1-5 Pacific Chemical Exposition, California Section, American Chemical Society, San Francisco Civic Auditorium.
2-4 American Society of Civil Engineers, fall meeting, Washington, D. C.
7-10 AIChE, annual meeting, Pittsburgh, Pa.
12-14 Geological Society of America, annual meeting, Hotel Cortez, El Paso.

DECEMBER
8-10 Seventh Annual Conference, Electric Furnace Steel Committee, Iron and Steel Division, AIME, Hotel William Penn, Pittsburgh.

FEBRUARY 1950
12-16 Annual Meeting, AIME, Statler (Pennsylvania) Hotel, New York City.

APRIL 1950
10-12 Open Hearth Conference, and Blast Furnace, Coke Oven and Raw Materials Conference, Nethland-Plaza Hotel, Cincinnati.

DECEMBER 1950
7-9 Eighth Annual Conference, Electric Furnace Steel Committee, Iron and Steel Division, AIME, Hotel William Penn, Pittsburgh.
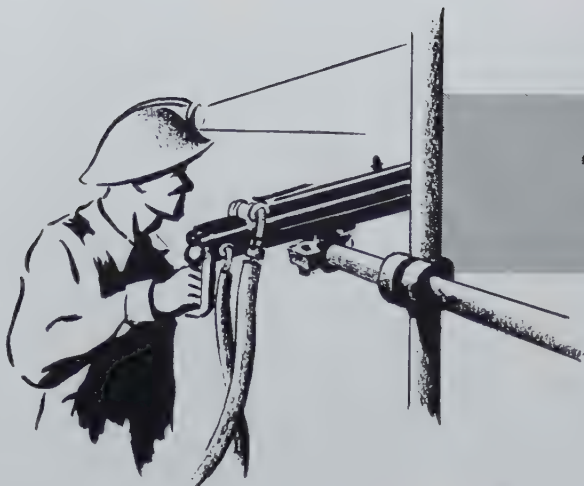
THE DRIFT OF THINGS

. . . as followed by EDWARD H. ROBIE

A "Have-Not" Nation

Palestine, and the new state of Israel, have been much in the news in the last year or two, but little has been said about its natural resources. We were therefore interested in a lecture given by S. H. Shaw not long ago before the Imperial Institute on the geology and mineral resources of the country. Briefly, we gather that whatever they have been fighting about in that part of the world, mineral wealth is not a consideration, as it is in so much of the world's strife.

The area of Palestine is only 10,400 sq mi—about that of Maryland or New Hampshire, and one tenth the size of Arizona, for instance—and of that a third is the southern desert or wilderness zone, roughly in Negeb and the part of the country to the south of it. Palestine is long and narrow—260 miles long, and the maximum width, between the Mediterranean and the Dead Sea, is 70 mi. It has three distinct topographical zones or strips running north and south — the coastal plain, the hill country, and the Dead Sea rift valley. It is practically all sedimentary country, not older than Cretaceous, with the hill country made up of hard and well-bedded Cretaceous and Eocene limestones, chalks, and dolomites. Pre-Cambrian country is limited to a few square miles at the southern tip, where micaceous schists and granite occur.

The most important mineral to the economy of the country is water, but there is not much of it over most of the area. Surface supplies are scanty almost everywhere, and in the arid parts of the country to the south water is practically unobtainable. Supplies are extremely scant in the hill country as well.

But the greatest mineral resource of Palestine lies in the water of the Dead Sea, which contains about 27 per cent of mineral matter, chiefly the chlorides of magnesium, sodium, calcium, and potassium, in that order, and magnesium bromide. Palestine Potash Ltd. has extensive treatment plants and produces potash, bromine, and salt, with plenty of magnesium chloride also available if anybody wants it.

The dolomitic limestones are extensively quarried for building stone, lime-burning, road stone, brick, and cement making, and use as a soil conditioner. Rock salt is obtained from solar evaporation of sea water as well as from treating the Dead Sea brine, and immense deposits can be mined if needed.

That about sums up the mineral resources. A little feldspar and barytes have been found, and unpromising deposits of sulphur, phosphate, manganese, and even copper are known. Three areas have possibilities of oil— the coastal plain, the Negeb, and the southern end of the Dead Sea, the last-named perhaps being the most promising, for bituminous limestones are present, which characterize so many of the oil fields of the Near East. A salt mountain exists here but it is perhaps not what oil men think of as a salt dome, for bedding exists in the salt, conforming with that of the sediments. But its presence does indicate the possibility of suitable structural traps for the accumulation of oil, although the faulted nature of the area may indicate that any oil has been dissipated rather than conserved. Exploration is going on.

Lack of mineral resources is always a handicap to a nation, though not a critical one, as many small nations have proved. The Jews are sufficiently resourceful and talented to find ways to make a living other than by the exploitation of mineral resources.

What Are Profits?

Proponents of wage increases for union labor, confronted with the argument that such wage increases will immediately be offset by higher prices, thus continuing the inflation spiral, reply that higher wages can easily be paid out of swollen profits and if capital would only be satisfied with a normal profit, no increase in prices would be necessary. It is true that profits of many if not most companies have been considerably greater than what might be considered normal, and that dividends have been consequently higher, but it is often forgotten that these profits and dividends are expressed in dollars and the dollar is now worth only sixty cents, or thereabouts. By the same argument, wages should revert back to the prewar scale.

We had in mind continuing on this subject for a paragraph or two or three when we ran upon a statement made by our own Joseph E. Pogue before a Congressional subcommittee on business profits, entitled "The Function of Profits in the Petroleum Industry." He states the matter much better than we could, and furthermore this is Washington's Birthday and we shouldn't have to work.

"The term profits," says Dr. Pogue,

"is a popular expression, the technical counterpart of which is 'net income.' Net income, or profit, however, at best is an accounting interpretation or abstraction, not a reality or tangible quantity such as 'cash in the till.' According to accounting practice, it is determined by taking the total income received by an enterprise and deducting the operating expenses and taxes, and then subtracting an *estimate* of the extent to which the capital assets employed have been extinguished; that is, worn out and used up. The sum thus set aside out of the total cash produced is supposed to be sufficient to replace the facilities of the business so that it can continue as a going concern. It is obvious that the adequacy of the sum thus set aside for replacement determines the reality of the reported net income. It is equally clear that 'profits,' depending for their computation on an estimate, are themselves not an absolute quantity.

"There are four basic conditions which should be clearly held in mind by anyone seeking to analyze the size and significance of profits. I shall try to define these four principles and then briefly illustrate each point by data taken from our study of 30 oil companies.

"(1) In times of inflation, or rapid change in the purchasing power of the dollar, 'profits' as reported on the basis of established accounting practice are in effect overstated by the amount of the rise in replacement costs over the sum set aside to cover capital extinguishments — depreciation, depletion, and the like.

"(2) In times of inflation, reported 'profits' cannot properly be compared with previous years because of the shrinkage in the purchasing power of the dollar. Only by correcting for the changing length of the yardstick can this be done with any semblance of accuracy.

"(3) In times of inflation, the rate of return on the capital employed, ordinarily a very useful standard, cannot be used as a criterion of the magnitude of profits because the rate of return is a ratio between two sets of dollars of different values. It is a mathematical error to strike a ratio between things of a different kind. Only by adjusting either the capital

employed or else the 'profits' to like dollars is such a ratio permissive.

"(4) In all times, inflationary or normal, the most effective criterion to apply in the judgment of 'profits' is their adequacy or inadequacy in the process of capital formation. Our entire economy is dependent upon the formation of sufficient capital funds to maintain and expand the country's productive capacity. As capital costs rise, 'profits' are called upon to supply increasing amounts of these funds.

"The reported net income of thirty oil companies was $763,000,000 in 1946 and $1,219,000,000 in 1947, an increase of $456,000,000, or 60 per cent. On the face of it, this increase appears large. But the charges for capital extinguishments (depreciation, depletion, etc.), designed to recover the capital funds extinguished during the year, were inadequate to replace the physical counterpart of this capital at prevailing higher costs. 'Profits' were therefore called upon to make up the discrepancy and part of the reported total was diverted to this purpose. Thus 'profits' computed by accounting procedure were larger than *de facto* profits. In other words, the *increased* cost of replacement appeared on the books as a profit."

Better Gasoline

Postwar motor fuels are much superior to the wartime grade, as every motorist has found by experience; they are also better than the prewar quality, and are getting better all the time. This statement refers primarily to the antiknock characteristics, which, to the average motorist, is the best index of quality. The latest Bureau of Mines report, based on samples taken last summer, indicates that the octane rating of first-grade gasoline (known as "ethyl gas") in various sections of the country varied from an average of 77.7 in the central plains area, where they don't have mountains to climb, to 82.1 in the Pacific Northwest, the countrywide average being 79.5. Second-grade (or "regular gas") varied from 72.8 in the South Mountain States to 77.3 in the Mid-Atlantic and New England States, the national average being 75.2 This compares with an average of 75.1 in the summer of 1947 and 74.4 in 1946. The premium

grade figure of 79.5 in 1948 compared with 79.2 the previous summer, 78.3 in 1946, and 74.9 in 1945. In other words, the so-called regular grade of gas we are now getting is better than the ethyl grade we were offered in 1945. However, the compression ratio of automobile engines is increasing, which means they must have a gasoline of higher octane rating in order not to knock. If the compression ratio were greatly increased the engines would be much more efficient, but would require a gasoline with an octane rating of something like 100, as do airplane engines, and that would cost enough more to offset the increased efficiency, in whole or in part.

The Bureau's figures do not distinguish between the different brands as to octane ratings, which information would, of course, help motorists in gauging the relative qualities of the various gasolines offered.

If a motor knocks, however, it is not usually necessary to buy a more expensive gasoline to make it run quietly—a simple adjustment in the vacuum line, or an adjustment of the spark may be all that is necessary. In other words, the motor may be adjusted to the gas, as well as the gas selected for the motor.

Better quality of motor fuels and lubricants year by year, as well as a plentiful and comparatively cheap supply compared with many other commodities, is something for which the owners of some 40,000,000 American cars can thank the petroleum industry.

Embarrassing Moment

Nothing recently has been a greater surprise to us than when, in browsing through the March issue, we came to page 74 of the All-Institute Section. This page had been carefully concealed from us until the issue appeared, and the preliminary work had been done during our absence in San Francisco. For seventeen years we had been successful in keeping even our picture out of the paper, and now they do this to us. Immediately after concocting this, Frank Sisco had the good sense to make plans to leave the country, and when that issue reached its readers, he was well on his way to an unknown spot in South America.
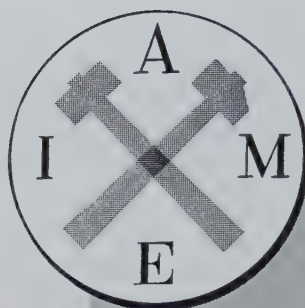
ALL INSTITUTE SECTION

New Board Meets for the First Time in San Francisco

Twenty-five of the 36 Directors of the Institute were on hand for the Board meeting held during the Annual Meeting of the Institute in San Francisco, on Tuesday, Feb. 15, immediately following the annual business meeting, when the newly elected officers and Directors took their seats. Of the new group, L. E. Young, William Coulter, Lloyd E. Elkins, James L. Head, Howard A. Meyerhoff, E. R. Price, Frederick N. Rhines, John D. Sullivan, and George P. Swift were present. President Young presided for the first time. Most interest centered on a resolution drawn up by the Section Delegates after extended discussion at two sessions the day before. when they voted, 31 to 6, that the Board should consider raising the dues of Members and Associate Members from $15 to $20, and of Junior Members from $10 to $12, for the next three years, at which time a referendum would be taken as to whether or not the increase should be continued. The hope is that in three years the accumulated deficit of the last two or three years can be wiped out and that advertising income will be sufficient by that time to supplement the income from dues at the present rate so that the budget can be balanced. The Board voted to accept the resolution of the Section Delegates and to

take the necessary steps to make an increase in dues for 1950 effective. This will involve a change in the by-laws and a referendum of the voting membership in the United States, Canada, and Mexico. Data to show why the increase is necessary if the present services of the Institute are to be continued or expanded will be supplied to all Institute members before the referendum is taken.

Much interest was also shown in the report of the Committee on Democratization, Joseph L. Gillson, chairman, with George Corless and E. A. Anderson. Dr. Gillson distributed copies of his report to all Directors present, and discussed his findings in some detail. The six principal recommendations were stated in the report of the January Board meeting on p. 137 of Sec. 2 of the March issue of this journal. The Board accepted the report with thanks, with the promise that such of its recommendations as can be financed will be put in force if found desirable by the Directors after study. A report of such study is to be made at the April meeting of the Board, at which time a further report from Dr. Gillson's committee was also invited.

Attention was called to the fact that at its meeting in November 1947 the Board had decided not to issue an

AIME Directory in 1949 and that action was approved by the 1949 Board because of the expense that would be involved. The 1948 Directory had cost $14,000, and printing costs have since risen. A list of all officers, committee personnel, and other newly revised matter will be published in Section 2 of the monthly journals during the spring.

Authorization was voted to proceed with a new and completely revised edition of "Coal Preparation" which has recently become out of print. David R. Mitchell will again be the editor and it is hoped that the book can be published before the end of the year. An additional amount of $6000 was also appropriated from the Seeley W. Mudd Fund for the new edition of "Industrial Minerals and Rocks," supplementing the original appropriation of $10,000. Typesetting on the revised book is now well along and the volume should be ready early in the fall. A request that some 2000 copies of the recently published book by Robert E. Hardwicke on the effect of antitrust laws on the unit operation of oil and gas pools be distributed to libraries will be considered further at the March meeting.

Six major awards were authorized for presentation at the Annual Meeting in 1950 if the respective committees can agree on candidates. They are the Rand, Saunders, Douglas, Lucas, and Ramsay medals, and the Richards award. The committee will

welcome suggestions as to the names of men deserving the honors.

Chairmen of certain new standing committees of the Institute were named, the complete list to be announced at the March meeting.

Dates for the next four meetings of the Board of Directors were set as follows, each date falling on a Wednesday: March 16, April 20, May 18, and June 15.

At the request of Dr. Rhines, consideration was given to the proposal that a publication manager, or advertising manager, be secured to promote advertising in the new journals, as suggested by the Johnson Committee,

Discussion at some length is planned for the March meeting of the Board and in the meantime Mr. Schumacher, with two other committee members to be selected by him, will study the advertising situation in respect to the *Journal of Metals*.

An Affiliated Student Society, comprising a group of students majoring in geology at the University of Wichita, was recognized. J. R. Berg is Faculty Sponsor and Edward A. Koester, Counselor.

The open meeting of the Board was preceded by an executive session at which the personnel of the Executive and Finance Committees for the coming year were named as follows:

Executive Committee

L. E. Young, chairman
Donald H. McLaughlin, vice-chairman
A. B. Kinzel   Earle E. Schumacher
John R. Suman

Finance Committee

Erle V. Daveler, chairman
Philip Kraft   Clyde E. Weed

Andrew Fletcher was unanimously re-elected Treasurer for the ensuing year, and Edward H. Robie, who had been Acting Secretary since Sept. 1 last, was elected Secretary.

Among the Student Associates

City College of New York

The Student Chapter at CCNY met on Jan. 14 to fill the offices left vacant by graduations. Herbert Feely is the new President; Jack Tarr became Vice-President; Julius Jettelson was named Secretary; and Seymour Feerst is Treasurer.—*Herbert Feely, President*.

University of Nevada

The Crucible Club of the Mackay School of Mines ended the year 1948 with publication of their semi-annual "Mackay Miner", and two interesting sessions with prominent guest speakers. Don White, Bureau of Mines geologist, spoke on Dec. 3, illustrating his topic "Volcanoes, Hotsprings and Ore Deposits" with slides. W. H. Denning, of the United Geophysical Co., was the year's final speaker, accenting new geophysical methods of finding oil in Brazil, and emphasizing the opportunities in geophysics which await young graduates.

The Club requests former students and graduates to forward their current addresses for the "Mackay Miner" mailing list.—*William D. Wiliams, Secretary*.

Illinois Institute of Technology

Forty-five members of the Illinois Institute of Technology Chapter of AIME have just completed their first, and highly successful semester at the

school. Under the aegis of President Edward Murway, a weekly program of movies and guest speakers was followed, and the Chapter also managed to find time to put a basketball and volleyball team into intramural competition.

Edward Lever, Vice-President; Robert Domagla, Secretary; and Treasurer John Cordes, will hold down those positions, along with President Edward Murway, until June elections. T. S. Washburn, of Inland Steel, is the Chapter's Counselor. Both he and H. M. St. John, of the Crane Co., have addressed the Tech Chapter. Otto Zmeskal and Lucio Mondolfo are Faculty Sponsors.—*Robert Domagla, Secretary*.

Oregon State College

The Student Chapter at Oregon State College was reactivated in January, and new officers were elected at an informal meeting. Ronald F. Robberson will henceforth wield the gavel, and James G. Osborne, Jr., is Secretary. Dr. Ira S. Allison remains as Faculty Sponsor.

The Chapter's new Counselor, F. W. Libbey, director of Oregon's Department of Geology and Mineral Industries, who spoke at the group's first formal meeting, found many interested listeners to his talk on bauxite occurrences in northwestern Oregon.—*James G. Osborne, Jr., Secretary*.

What Went on at Recent Local Section Meetings

SECTION	DATE	PLACE	PRESIDING OFFICER	ATTEND-ANCE	SPEAKER, AFFILIATION, AND SUBJECT
Arizona, Ajo Sub-section	Feb. 2	Ajo....................	William Keener......	23	Jack Sheridan, Chile Copper Co., on Mining at Chiquicamata.
Boston...........	Feb. 7	Smith House, Cambridge....	George P. Swift......	65	J. N. Hobstetter, Harvard Univ., on Diffusion in Metals.
Carlsbad Potash....	Feb. 17	Carlsbad.................	G. E. Atwood........	58	John A. Frost, USGS, "Down the Colorado With Homemade Boat & Kodachrome."
Chicago...........	Feb. 2	Chicago.................	T. S. Washburn......	123	S. J. Creswell, Carnegie-Illinois Steel Corp., on Recent Developments of the Bessemer Process.
Cleveland........	Jan. 13	University Club...........	John M. Kiefer.......	....	Carl F. Prutton, Lubrizol Corp., on Lubrication and Lubricant Research.
Columbia..........	Feb. 4	Davenport Hotel, Spokane...	Howard Sherman.....	28	Eugene Roberts, Merrill, Lynch, Pierce, Fenner and Beane, on Money at Work.
Connecticut.......	Feb. 9	Waterbury...............	R. S. French........	40	R. D. Heidenreich, Bell Telephone Laboratories, on Electron Microscopy and Electron Diffraction.
Delta, Mississippi Subsection	Jan. 28	Jackson, Miss............	W. W. Ramseur......	55	H. G. Dewey, Jr., Chief, Miss. Basin Branch, Waterways Experiment Station, on The Waterways Experiment Station.
El Paso Metals.....	Feb. 9	Hotel Cortez, El Paso.......	Edward M. Tittman..	39	W. D. Sydnor, Jr., Guided Missile Dept., Fort Bliss, Texas, on The Principle of Jet Propulsion.
Kansas...........	Feb. 9	Great Bend, Kans.........	V. J. Mercier........	85	Roscoe Clark, Stanolind Oil & Gas Co., on Proper Cementing of Casing.
Mid-Continent.....	Feb. 14	Tulsa, Okla...............	John P. Hammond...	62	Jack Webber, Atlantic Refining Co., on Hydraulics in the Use of Oil Well Packers.
North Pacific......	Jan. 20	University of Washington...	Kenneth H. Anderson	95	Ralph A. Sherman, Assistant Director, Battelle Institute, on Fuels for Today and Tomorrow.
Southeast, Florida Subsection	Nov. 1	Bartow, Fla...............	E. S. Beebe..........		W. H. Twenhofel, Emeritus Professor, Univ. of Wisconsin, on Sedimentation. Dr. Rodgers, Stanford Univ.
Southeast..........	Jan. 19	Molton Hotel, Birmingham..	J. C. Gray..........	30	P. O. Powers, Battelle Institute, on Plastics as Applied to Mining, Metallurgy and Coal.
Southwest Texas...	Feb. 9	Corpus Christi............	Raoul J. Bethancourt	277	M. M. Kinley, M. M. Kinley Co., talk and films on Oil Well Fires and Blowouts.
St. Louis..........	Dec. 10	York Hotel...............			S. S. Clarke, General Superintendent of Mines, Eagle-Picher Co., on Underground Mechanization in the Tri-State District.

Colorado School of Mines

A review of the last fifty years in the coal mining industry was presented by Thomas Allen, Colorado State coal mine inspector, at the Jan. 13 meeting of the Student Chapter at Colorado's School of Mines. Mr. Allen enlivened his speech on past and present mining methods, labor relations and government control with personal anecdotes drawn from his own experiences.

At the Feb. 10 meeting, President Herman Knight introduced Alfred Crofts, of Denver University's history department, who spoke of the young engineer's responsibility and future in a world of changing foreign and domestic social conditions. A question and answer period followed Dr. Knight's talk.— *Harvey W. Smith, Public Relations Chairman.*

University of Idaho

The Associated Miners of the University of Idaho were regaled at a banquet on Jan. 6. Eighty assembled members and guests were addressed, and saw movies shown by petroleum geologist John B. Miller, who heads the photogrammetric division of an American oil company in Colombia. His films portrayed native life, agriculture, industry, geology, and geography of the South American nation. — *A. G. Randall, Secretary-Treasurer.*

Missouri School of Mines

A record-breaking crowd of 243 men turned out for the Feb. 10 meeting to view two interesting movies and enjoy the usual refreshments. The first movie, "Lead Smelting at the St. Joseph Lead Co.," pictured all the steps in changing ore to lead, both in milling and smelting. The second, "The Army-Navy Football Game" was highly entertaining, and perhaps even educational. This Chapter is looking forward to breaking their new attendance record within a short time. — *Albert A. Jones, Secretary.*

South Dakota School of Mines

Not even a blizzard could stop Drill and Crucible Club members from gathering on Jan. 27 to hear Al Needham, of the Bureau of Mines, speak on reverse core drilling and present his own movies of the process. Also on the agenda for that night was the general superintendent of the Braden Mines in Chile, who gave a highly informative talk on block caving methods.

At the Club's Dec. 7 meeting, three movies were shown, all highly recommended to other Chapters. They were: The Story of Copper, Nickel Milling and Smelting, and one about the Homestake Gold Mine at Lead, S. D. The first two were provided by the Bureau of Mines Graphic Services Section in Pittsburgh. The above mentioned blizzard didn't even dent the Club's new attendance records, which have so far doubled last year's average of 35 at each meeting.—*Russell J. Gamberg, Secretary.*

News of AIME Members

John E. Bowenkamp

Charles S. T. Farish

Henry M. McLeod, Jr.
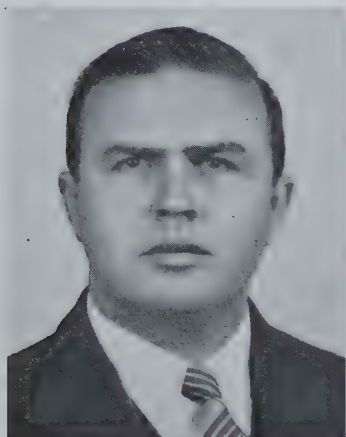
John E. Bowenkamp returned to Colombia in February after a combined vacation, leave of absence, and business trip to the United States and Canada. Now that he is back in Medellin he will continue to carry on in his capacity of mine examination engineer for Wellington Explorations Ltd., a subsidiary organization of the N. A. Timmins Corp. of Montreal. His airmail address is Apartado Aereo 817, Medellin.

William H. Bradbury graduated from the University of Colorado last August with a B.S. degree in chemical engineering and is now employed as an assayer for the Cia. Minera del Mexcala, Gro., Mexico.

John B. Breymann, III, after finishing his studies at MIT, is working for the Shenandoah-Dives Mining Co., Silverton, Colo.

Frank Cameron is working for the Saudi Arabian Mining Syndicate, Jeddah, Saudi Arabia. He had been living in Jenkintown, Pa.

J. A. Caverly, now with the Gardner-Denver Co., Quincy, Ill., used to work at the Snow Lake division of the Howe Sound Exploration Co., Snow Lake, Man.

A. J. Cayia has been elected president of the Inland Lime and Stone Co. He has been with the Company since 1928, and was formerly a mechanical engineer for the M. A. Hanna Co.

Charles S. T. Farish has been promoted to general superintendent of mines of the Cerro de Pasco Copper Corp. at La Oroya, Peru. He has been with Cerro since 1919 as mine engineer, general mine foreman, tunnel foreman, assistant superintendent, and superintendent.

L. M. Abell left Fiji, where he was with the Emperor Gold Mining Co., Vatukoula, last November, spent a few weeks in Canada and the States and then went on to Skouriotissa, Nicosia, Cyprus, where he is mill superintendent for the Cyprus Mines Corp.

Bert C. Austin, president of Bert C. Austin & Co., of San Francisco, is doing the consulting engineering work on the Vivian Mining Co.'s recently leased Pine Hill mine, in the Wolf district, southwest of Grass Valley, Calif.

Richard C. Badger, vice-president of Park City Cons. Mines Co., is directing the rehabilitation operations at the Company's Park City, Utah, property which had been shut down for five years.

Daniel F. Flowers is engineer for the Differential Steel Car Co., Findlay, Ohio, and gets his mail at 1109 S. Main St., Findlay.

Donald W. Frommer has established a permanent address at 16 Great Oaks, Rolla, Mo. Since last August he has been employed by the Rolla station of the Bureau of Mines, working on flotation and other types of mineral dressing.

Henry M. McLeod, Jr., who for the past three years was a project leader in T.V.A.'s process development division at Wilson Dam, Ala., has accepted a job with the research and development division of the Carbide and Chemicals Corp., at Oak Ridge, Tenn. His address is 110 Porter Rd., Oak Ridge.

Louis C. Ball has been appointed geologist of the Standard Gypsum Co. with headquarters in the Kaiser Bldg., Oakland, Calif. He worked for the Aluminum Co. of America before serving as a naval officer for two years during the war, seeing action during the Okinawa campaign and the subsequent minesweeping in Japanese waters. In 1946 he joined another Henry J. Kaiser operated company, the Permanente Metals Corp., and was engaged in the exploration of bauxite land under option in Surinam, Dutch Guiana.

Edward G. Fox, who has been president of the Shen-Penn Production Co., has become general manager of the Philadelphia and Reading Coal and Iron Co., Pottsville, Pa.

H. S. Fowler left his post as general superintendent of the Blubber Bay plant of the Pacific Lime Co. early in October to join the engineering staff of the Denver Equipment Co., Denver, Colo.

Percy Gardner, Jr., has the job of engineer with the Silver Dollar Mining Co. at Wallace, Idaho.

William D. Leonard, of 4416 View St., Oakland 11, Calif., is manager of the Emprise Sales Co.

David E. Morgan

David E. Morgan is traveling in European and African mining territories, representing various American mining equipment manufacturers and is also acting as a consulting engineer for foreign mining companies. He can be reached through his New York City office at 220 Broadway.

Ronald K. Sorem has taken the job of geologist with the U. S. Geological Survey in Washington, D. C.

Robert L. Swain is employed in Kimberly, Nev., as an underground engineer for the Consolidated Coppermines Corp. His mailing address is Box 206, Kimberly.

Glen C. Taylor has moved to Evans, Wash., where he is employed by the U. S. Gypsum Co. as a plant engineer.

Robert E. Thurmond is in Jerome, Ariz., where his mail is received at Box 1423, and his job is geophysical field engineer for the Newmont Mining Corp.

Frank E. Tippie can be reached in care of Cia. Minera y Refinadora Mexicana, Estacion Wadley, S. L. P., Mexico. He had been with Patino Mines and Enterprises Consolidated in Bolivia.

Theodore Toren, Jr., formerly with Day Mines, Inc., Wallace, Idaho, is employed by the Oliver Iron Mines in Hibbing, Minn. His new address is 1029 W. 29th St., Grand Rapids, Minn.

Abner A. Towers has been transferred from the New York office of the Dorr Co. to the Atlanta office. His new address is 2421 Sagamore Dr., Atlanta N. W., Ga.

N. de Voogd is general manager of Metalurgia Jofremars, Caixa Postal 38, São João del Rey, Minas Gerais, Brazil. Since October he has been in charge of operations at three properties of the Company, all situated in the São João del Rey tin belt, where he hopes to develop vein and placer mining and a small smelter.

H. A. Waite left Salt Lake City the end of December to go to Honduras as general superintendent of the New Idria Honduras Mining Co., Santa Rosa de Copan, Honduras.

Arnold H. Walker, formerly with Sladen Malartic Mines Ltd., is now working for Barnat Mines Ltd., Box 33, Malartic, Que.

Joseph J. Wallace, formerly a student-trainee with the Pittsburgh Coal Co., has joined the staff of the Bureau of Mines at Pittsburgh as a mining engineer.

Robert H. Wheless, who had been a student at the University of Alabama, is working at the Praco mine of the Alabama By-Prod Corp., Praco, Ala.

Harold H. White

Harold H. White severed a twenty-year connection with the Atlas Powder Co. on Feb. 1, to take charge of a newly formed consulting engineering company composed of Texas engineers and scientists. Chief company operations will be the control of blasting in settled areas, and measurement of blast vibrations. Mr. White was instrumental in the formation of Atlas's subsidiary company in Mexico, and directed its operations until 1947. His new firm's headquarters will be in Houston, with branches in New York, Chicago, and Cleveland, rounding out the nation-wide scope of operations.

T. A. Woods-Smith has moved from Los Angeles, and is now associated with Patiño Mines and Enterprises Consolidated, Siglo XX, Llallagua, Bolivia.

Dan S. Young, former chief engineer and geologist for the Castile Mining Co., has gone to Montreal, Wis., where he is associated with Oglebay Norton and Co.

• In Petroleum Circles

Forrest J. Allen, Jr., graduated from the University of Oklahoma in January and has gone to work for the California Co., 1818 Canal Bldg., New Orleans 12, La.

Donald L. Bohannan has moved to Wyoming with the Stanolind Oil and Gas Co. His address is P. O. Box 966, Midwest, Wyo.

Ira H. Cram has changed his address for mail from the Pure Oil Co. of Chicago to the Continental Oil Co., Ponca City, Okla., being a vice-president of the latter company.

Jack D. Duren is working for the Shell Oil Co. as a junior exploitation engineer. Mail reaches him at 521 E. First St., Trinidad, Colo.

Patrick N. Glover, exploitation engineer for the Shell Oil Co. at Los Angeles, lives at 829 S. Bundy Dr., Los Angeles 24, Calif.

Wilber H. Griffin, who was with Baker Oil Tools, is general sales manager for CAMCO, Inc., manufacturers and distributors of Camco gas lift equipment, in Houston. His permanent address is 1601 S. Shepherd Drive, River Oaks Gardens, Houston 19.

David P. Hoover has been working on a trainee program sponsored by the Gulf Oil Corp. with an address at 506 LaFayette, Pittsburg, Texas.

Alden J. Laborde, whose last address was in New Orleans, is now marine superintendent with Kerr-McGee Oil Industries, Morgan City, La.

Billy B. Lane is working as a field engineer for the Sohio Petroleum Co. at Eureka, Kans.

Philip Maverick, Jr., is a petroleum reservoir engineer with the Phillips Petroleum Co., 219 S. Big Spring St., Midland, Texas.

Neal McCaskill has returned from Venezuela, where he was working as a petroleum engineer with the Venezuela Atlantic Refining Co., and can now be reached at 1708 16th Street, Lubbock, Texas.

Paul M. McMinn, formerly at the University of Wisconsin, has moved to Denver, Colo., to work for the California Co.

Roderick G. Murchison resigned from the Socony-Vacuum Oil Co. of Colombia in March 1948 and since that time has been instructor in geology at the University of North Carolina, Chapel

Hill. His permanent address remains P. O. Box 547, Rocky Mount, N. C.

F. Ward O'Malley has joined the exploration department of the Continental Oil Co. and is working at the Denver office, Rm. 1029, Continental Oil Bldg.

E. R. Osburn is reached now in care of the Union Producing Co., P. O. Box 1422, Monroe, La.

Harold E. Parsons transferred on Jan. 20 from Lima, Peru, where he has been for almost four years, back to Bogota, Colombia, still with the same employers, Socony-Vaccum Oil Co. His work in Bogota will be much the same as he was doing in Peru, where he was working on photo-geological mapping, with several extended field trips in the montaña—the jungle lowlands east of the Andes in the region of the upper Amazon drainage. He expects to return to the States on leave some time this summer. His address is Apartado Nacional 1140, Bogota, Colombia.

L. F. Peterson has terminated several years service with the Stanolind Oil and Gas Co., to join as a partner in the Midland, Texas, consulting firm of Henderson, McMillian and Peterson. The firm will handle petroleum geological and engineering problems, property management, leasing, title examination, and well completions.

Darrell S. Pierson, no longer a student at the University of Utah, is employed by The Texas Co. producing department at Sunburst, Mont., as a petroleum engineer-trainee.

Floyd W. Preston is now a research engineer with the California Research Corp., a Standard Oil Co. of California subsidiary, at La Habra, Calif. He joined the Company recently, after receiving his M.S.E. degree from the University of Michigan.

Claude O. Stephens is now in Worland, Wyo., working for the Texas Gulf Sulphur Co. His address there is P. O. Box 15.

Arthur G. Sullivan, Jr., no longer a student at Texas A&M, is a junior petroleum engineer with the Ohio Oil Co., with a new address at 121½ Old Kilgore Highway, Henderson, Texas.

Robert P. Thomas is now employed as a junior seismologist in training with the Shell Oil Co. He expected to receive his M. A. degree from the University of California in February.

William H. Wadlington, having finished his studies at Texas A&M, is a junior petroleum engineer with the Stanolind Oil and Gas Co., Box 1518, Levelland, Texas.

Arthur L. Jenke

Arthur L. Jenke is now in Abilene, Texas, where he is associated with Riley Maxwell, consulting geologist. Mr. Jenke's chief interest is in the operation of a core testing laboratory which he set up several months ago in the West Texas city. Prior to his venture into the consulting field, he attended Washington University in St. Louis, receiving a M. S. degree in geology last June. During the academic year 1947-1948 he held a Shell Oil Co. fellowship in geology. A tenure of approximately seven years with the U. S. Geological Survey was brought to a close with his resignation last May.

Karl L. Wehmeyer, Jr., has been appointed resident geologist of the Mene Grande Oil Company's Bolivar coastal fields. His address is Geological Dept., Apartado 234, Maracaibo, Venezuela.

Norman Wilson is district geologist for the Great Lakes Carbon Corp., 417 Indiana Bank Bldg., Evansville, Ind.

• In the Metals Divisions

Donald H. Beilstein has the job of junior metallurgist in the Federated Metals division of the AS&R Co. in San Francisco. His home address is 272 Everett Ave., Palo Alto, Calif.

William W. Berkey is working for the Kaiser-Frazer Corp. at Willow Run, Mich., as a metallurgist.

Jay R. Burns is now employed as a research engineer in the process development department, magnesium division of the Dow Chemical Co. He had been chief of the magnesium unit, materials laboratory, Wright-Patterson Air Force Base.

John M. Crockett is assistant metallurgical engineer with the Air Reduction Sales Co., New York City. His mail goes to 23 Bounty St., Metuchen, N. J.

Edmund C. Franz is in Cleveland, Ohio, now, working for the Aluminum Co. of America, 2210 Harvard Ave.

Emerson L. George is a junior engineer for McConway Torley Inc. of Pittsburgh. His home address is 219 Oakland Ave., Apt. 31, Pittsburgh 13.

Russell G. Hardy has moved from Baltimore, Md., where he was with the Gibson & Kirk Co., to Chicago to work for the Argonne National Laboratories. His address is 1550 E. 61 St., Chicago.

Frederick A. Hartgen is sales manager and metallurgist for Nutmeg Crucible Steel, Branford, Conn.
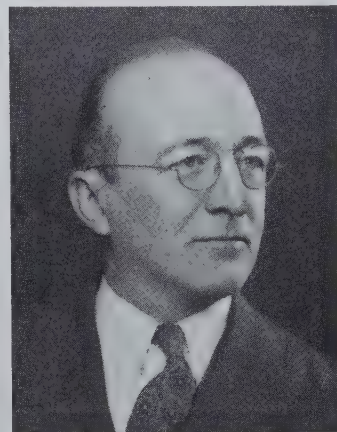
Alexander L. Feild

Alexander L. Feild, associate director of research for the Armco Steel Corp., was awarded an honorary degree of Doctor of Science on Feb. 5 by the Stevens Institute of Technology, Hoboken, N. J. A Tarheel by birth and education, with degrees from the University of North Carolina and from N. C. State College, he has worked for his state agricultural department and for the U. S. Bureau of Mines. For the last thirty years he has been a research man in industry, during which time 28 U. S. patents have been awarded to him.

David W. Pettigrew, Jr., who graduated from the Carnegie Institute of Technology last June with a B.S. degree in metallurgy, has returned to the Aluminum research laboratories of the Aluminum Co. of America, New Kensington, Pa., where he is employed as a research engineer in metallography.

Morris Steinberg, of the metallurgical division of Horizons Incorporated, has ben appointed head of the division. Dr. Steinberg received his doctorate from MIT in June, 1948, and joined the staff of Horizons at that time. He is co-author of "Lead-grid Study of Metal Powder Compaction" presented at the Annual Meeting in San Francisco in February.

Robert C. Stanley

John F. Thompson

Paul D. Merica

Robert C. Stanley, president since 1922, director since 1917, and chairman and president since 1937 of the International Nickel Co. of Canada, continues as chairman of the board, while **John F. Thompson,** who has been an executive vice-president since 1936 and a director and member of the executive committee since 1931, has become president. **Paul D. Merica,** vice-president since 1936 and a director, is now executive vice-president. Under Mr. Stanley's chairmanship, International Nickel has become the world's largest producer of nickel and platinum metals and the largest copper producer in the British Empire. Recently he resigned as chairman of the trustees of Stevens Institute of Technology, after serving for twelve years. Dr. Thompson joined the Company as a metallurgist in 1906, becoming manager of operations in 1921 and assistant to the president seven years later. He supervised the construction and initial operations of the Company's Huntington, W. Va., works, founded for the production of nonferrous alloys. For many years the Company's production in the States and its operations and markets in Great Britain and Europe have been among the matters in his particular charge. Dr. Merica has been with International Nickel since 1919, becoming director of research and later associate manager of the development and research department. In addition to his responsibilities as vice-president, he has continued to give special attention to the Company's research activities in Canada, the United Kingdom, and the States. He has evolved numerous iron-nickel and copper-nickel alloys and is the author of many technical papers and articles.

Donald D. Helman is working for the Ohio Steel Foundry Co., Springfield, Ohio, as a metallurgist.

Harry Hey has been made managing director of the Electrolytic Zinc Co. of Australasia, Melbourne, Australia.

Norton Jackson has left the Emperor Gold Mining Co., Vatukoula, Fiji Islands, to become metallurgical engineer for the Department of Mines, South Australia. His new address is 64 Tusmore Ave., Tusmore, S. Australia.

S. T. Jazwinski, vice-president of the Detroit Steel Casting Co., Detroit 10, Mich., has gone to Rio de Janeiro for several months.
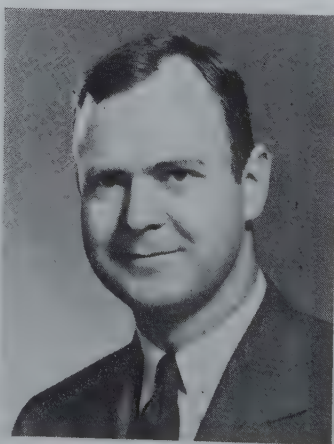
Bruce S. Old

Bruce S. Old has been elected to the board of directors of Arthur D. Little, Inc., research and engineering organization. Dr. Old joined the concern in 1946 after leaving the Navy, where he served in the Office of Research and Invention with the rank of Commander. He is now in charge of process metallurgy for Arthur D. Little as well as consultant to the Office of Naval Research and the Atomic Energy Commission, in the latter as chief of metallurgy and materials branch, Division of Research.

Peter J. Kassak, Jr., former University of Pennsylvania student, is now a cadet engineer with the Public Service Electric and Gas Co. of Newark, N. J. His address is 729 Colonial Ave., Union, N. J.

John R. Kunkel has left the Fansteel Metallurgical Corp. to work at the Ingersoll steel and disc division of the Borg-Warner Corp., Chicago. His mail is sent to 12409 S. Ada St., Chicago 43.

LeRoy H. Markway is working for the Shell Oil Co. at Wood River, Ill., as a junior engineer.

Raymond L. McGaughey graduated from the University of Illinois last summer with a degree of B. S. in metallurgical engineering. At present he is employed by the Elgin National Watch Co. as a research metallurgist. His mail goes to 1191 Logan, Elgin, Ill.

Whitney P. Mee has been retained as consulting metallurgist by Cia. Metalurgica Peñoles, a subsidiary of the American Metals Co. since August 1947. Most of his time has been spent at the Peñoles lead-copper smelter at Torreon, Coah., with periodic trips to the company's headquarters at Monterrey, N. L. Upon completion of an extensive construction program late this year, the capacity of this plant will have been practically doubled, and many improvements are being made which will make the Torreon smelter one of the most modern and efficient in Mexico. **Philip Doerr** is manager of the plant and **I. M. Symonds** is in charge of operations.

Wilbur L. Mudge, Jr., has taken the job of metallurgist with the Foote Mineral Co. of Philadelphia, and is continuing his graduate studies at the University of Pennsylvania. His address is 2840 Washington Ave., Apt. C, Camden, N. J.

Edward C. Nelson, former assistant metallurgist at the Naval Research Laboratory, Anacostia Station, Washington, D C., has joined the staff of Rensselaer Polytechnic Institute, Troy, N. Y., as an instructor in metallurgical engineering.

Robert M. Parke, who has been at the applied physics laboratory of Johns Hopkins University, is acting as technical adviser for Battelle Memorial Institute, Columbus, Ohio.

T. W. Plante, superintendent of blast furnaces for the Jones & Laughlin Steel Corporation's Eliza works in Pittsburgh, will go to Chile in the spring to be superintendent in charge of blast furnaces and raw materials for the Pacific Steel Co. of Chile. He will be in Pacific Steel's New York offices for a while and then make his home in Concepcion, where the Company is now building an integrated steel mill.

Kenneth L. Quigley is associated with Northern Ordnance Inc., Columbia Heights Station, Minneapolis, Minn. He was with the Champion Motors Co.

Edward J. Ramaley has accepted the post of tool design research engineer with the Lockheed Aircraft Corp., Burbank, Calif.

Fred Romano, former research metallurgist for the National Smelting Co., has taken over as superintendent of plant metallurgy for the Monarch Aluminum Mfg. Co., Cleveland, Ohio.

Carl H. Samans recently resigned as chief, metallurgy section, research laboratory, American Optical Co., Southbridge, Mass., and can be reached at the Engineering Research Dept., Standard Oil Co. (Indiana), 910 S. Michigan Ave., Chicago 80.

Eraldus Scala, who became a Student Associate in 1947 while attending Columbia University, is now employed in the research laboratory of Chase Brass & Copper in Waterbury, Conn. His new address is 31 Chipman St., Waterbury.

J. R. Scrivener, sales engineer with the Permanente Products Co., has transferred from the Chicago office to the Company office at 1924 Broadway, Oakland 12, Calif.

Tryggve Smedsland, native of Norway who attended the Missouri School of Mines, and joined the Institute last year as a Student Associate, is now back in his homeland, teaching at the Norwegian Institute of Technology in Trondheim. Members who would like to correspond with their Norwegian co-worker can reach him at the Department of Metallurgy, Norges Tekniske Högskole, Trondheim.

N. S. Spence recently was appointed director of research and development for Dominion Magnesium Ltd., Haley, Ont.

Frank T. Sisco

Frank T. Sisco, director of Alloys of Iron Research, was appointed technical director of the Engineering Foundation, effective March 1. The Foundation, joint research agency of the AIEE, AIME, ASCE, and ASME, sponsors and supports fundamental research in all fields of engineering. Mr. Sisco has worked in the operating departments of various steel companies and as chief of the metallurgical laboratory of the U. S. Army Air Corps at Wright Field, Dayton, Ohio. He has been in charge of Alloys of Iron Research since 1930 and for the present will continue this project.

David T. Steele has taken a job with the American Metal Co., 1 N. La Salle St., Chicago 2. He was with the Duquesne Smelting Corp., Pittsburgh.

P. L. Steffensen, former superintendent of the concentrator plant of the Bethlehem Steel Co., is manager of the Company's raw materials research, Lebanon, Pa.

R. J. Turney has been transferred from the Tacoma plant to the Selby plant of the American Smelting and Refining Co., 405 Montgomery St., San Francisco.

Joseph J. Warga, who was with the Owens-Illinois Glass Co., is now working for the Sperry Gyroscope Co., Great Neck, L. I., N. Y., on process and materials standards.

Harold K. Work became director of the research division of the College of Engineering of New York University on Feb. 1. He was manager of the research and development division of the Jones & Laughlin Steel Corp. Dr. Work is Vice-Chairman of the Institute's Iron and Steel Division.

Obituaries

James S. Douglas

AN APPRECIATION BY R. D. LEISK

James S. Douglas, "miner and banker," as he chose to be listed in the directory of the AIME, died at the age of eighty at his home in Montreal on Jan. 2. His passing marked the end of a notable career that left an indelible imprint upon the history of copper mining in the southwest.

He was born in Quebec in 1868. His illustrious father, James Douglas, was at the time engaged in the development of a chemical process for the treatment of copper ores, an activity which in 1875 necessitated moving from Quebec to Phoenixville, Pa., where James S. Douglas spent much of his boyhood. Dr. Douglas soon began to devote more and more of his time to the investigation of mining properties in the west and southwest and this resulted in an association with the late W. E. Dodge and D. Willis James that brought the old metal trading firm of Phelps Dodge and Co. into the copper mining business at Bisbee and culminated in the formation of the present Phelps Dodge Corp. of which Dr. Douglas was the first president.

With this background, James S. Douglas as a young man developed a keen interest in the growing mining industry of the southwest together with its requirements of rail transportation and finance. He investigated and operated a number of the early mining properties in Arizona and northern Mexico and later engaged in banking and other business. He was perhaps best known for his part in the discovery of the copper bonanza of the United Verde Extension in 1915 at Jerome, Ariz. Here with the help of an associate, the late George E. Tener, he took the lead in reorganizing and backing a venture started by L. E. Whicher. The UVX, as it was called, was a longshot geological gamble of no small proportions, involving the exploration of faulted Pre-Cambrian formations covered by some 800 ft. of sedimentaries and lavas. Under the direction of Jimmy

Necrology

Date Elected	Name	Date of Death
1940	Elwood Bachman	Dec. 16, 1948
1936	Arthur J. Boase	Unknown
1920	Charles E. Bruff	Feb. 25, 1949
1942	Mark G. Carhart	March 6, 1949
1918	Howard Drullard	Jan. 29, 1949
1916	Horace S. Gulick	Jan. 31, 1949
1938	Philip H. Holdsworth	Nov. 21, 1948
1932	Donald R. Knowlton	March 9, 1949
1935	Otto G. Leichliter	Sept. 8, 1949
1930	R. John Lemmon	Jan. 26, 1949
1916	Walter B. Miller	Sept., 1948
1936	Arthur S. Nichols	Feb. 18, 1949
1913	Walter V. Rohlffs	Unknown
1940	William A. Rose	Jan. 30, 1949
1945	James W. Starks	Feb. 3, 1949
1904	David Rhys Thomas	March 4, 1949
1892	Bailey Willis	Feb. 19, 1949
1916	Harold E. Willson	Unknown

Douglas, a new shaft was sunk and after many disappointments and the expenditure of much money the venture became a sudden and astounding success when a crosscut on the 1400 level penetrated what was probably the greatest body of high-grade chalcocite ore ever discovered. For three solid years thereafter the ore produced by this great mine averaged 23 percent copper and by the time the ores were exhausted in 1937 the shareholders had received over $50,000,000 in distributions. James S. Douglas served as president of the United Verde Extension Mining Co. until it was dissolved in 1939.

During the first World War he spent much of his time and personal funds in Red Cross work in France where he came to know and admire the wartime Prime Minister, Georges Clemenceau, after whom the UVX smelter town was later named. He wore the ribbon of a Chevalier of the Legion of Honor and for many years it was his custom to spend a month or two each year in France among the simple surroundings he loved so well.

Jimmy Douglas was by nature an aggressive individualist of the old school that contributed so much to the building of the West. He believed in simple and wholesome living and abhorred waste and extravagance. A shrewd trader, uncompromisingly honest in his dealings, he did business on the theory that a man's word should be as good as his bond and that a written contract was no better than the integrity of the signer. He was a man of high character and ideals, and while his approach to the solution of economic and business problems was characteristically simple and direct, he would not compromise principle for the sake of an easy solution. He appreciated art and good music and loved animals, especially the horses which had carried him over so many miles of mountain and desert in his younger days, and the little Arizona quail which came to look for crumbs at the doorstep of his house at Jerome. Well read, a deep thinker and good conversationalist, his opinions were his own and vigorously expounded, but he was nevertheless fair minded and respected the opinions of others so that an argument with him was a stimulating experience that always ended with increased mutual respect. He was a staunch and loyal friend as many who knew him came to realize in time of adversity. As a host he was charming, a courtly gentleman, and ever a good companion.

The memories of many pleasant visits with him at Jerome and at Douglas, Ariz., at the old family home at Spuyten Duyvil on the Hudson, and at Montreal and St. Pierre les Becquets, all carry with them the deep appreciation of having known James S. Douglas.

Proposed for Membership

Total AIME membership on February 28, 1949, was 15,326; in addition 3884 Student Associates were enrolled.

ADMISSIONS COMMITTEE
James L. Head, Chairman; Albert J. Phillips, Vice-Chairman; George B. Corless, T. B. Counselman, Ivan A. Given, George C. Heikes, Richard D. Mollison, and Philip D. Wilson.

Institute members are urged to review this list as soon as the issue is received and immediately to wire the Secretary's office, night message collect, if objection is offered to the admission of any applicant. Details of the objection should follow by air mail. The Institute desires to extend its privileges to every person to whom it can be of service but does not desire to admit persons unless they are qualified.

In the following list C/S means change of status: R, reinstatement; M, Member; J, Junior Member; AM, Associate Member; S, Student Associate; F, Junior Foreign Affiliate.

ARIZONA
Ajo—LEWIS, EVAN GERRIT. (R—M). Mill superintendent, New Cornelia branch, Phelps Dodge Corp.
Benson—TOWLE, LOUIS WALLACE. (M). Technical service supervisor, Apache Powder Co.
Superior—NOBS, KENNETH ASTREDO. (C/S—J-M). Level boss, Magma Co.
CALIFORNIA
Alhambra—FATT, IRVING. (J). Associate research chemist, California Research Corp. MUEHL, WALLACE WILLIAM. (M). Sales engineer, Link Belt Co.
Balboa—PYLES, ERNEST E. (AM).
Assistant to executive vice-president and general manager, Jergins Oil Co.
Berkeley—GORDON, GEORGE MALVEN. (C/S—J-M). Spectrographer, University of California.
Concord—RHODES, LOUIS CLIFFORD. (R,C/S—JA-M). District manager, San Francisco office, Joy Mfg. Co.
Long Beach—GORE, DAVID BELL. (M). Sales engineer, Eastman Oil Well Survey Co.
Piedmont—YOPES, PAUL FREDERICK. (C/S—J-M).
San Francisco—REEDER, DAVID BRIERLY. (M). Division manager, Electro Metallurgical Sales Corp. WITT, FRANK. (M). Consulting mining engineer; general manager, Western States Mining Co.
Santa Maria—EVANS, KENNETH RUSSELL. (M). Vice-president, Bell-Casmite Oil Co., and A. E. Bell Corp.
Taft—GRIVETTI, REX MICHAEL. (C/S—J-M). Geologist, The Texas Co.
COLORADO
Climax—COOLEY, CHARLES MILTON. (R,C/S—S-J). Engineer, planning dept., Climax Molybdenum Co.
Denver—HARRIS, JAMES DAWSON, JR. (R,C/S—J-M). District engineer, Rocky Mountain district, Core Laboratories, Inc. STEDMAN, ALAN LEROY. (C/S—S-AM). Construction engineer, Armco Drainage & Metal Products, Inc. WATSON, GEORGE CHARLES. (M). Owner, Domestic Coal Co.

Leadville—GREENLEE, BARNETTE BATES. (R,C/S—J-M). Mine foreman, Resurrection Mining Co.
CONNECTICUT
Ansonia—TOUSSANT, WILLIAM THEOPHILE. (M). Sales metallurgist, Bridgeport Brass Co.
Hartford—DORVEL, ARNOLD ALEXANDER. (J). Metallurgist, Hartford Electric Steel Co.
Riverside—BEAN, JAMES JOSEPH. (M). Mineral dressing engineer, American Cyanamid Co.
Stamford—ANDERSON, ELWOOD ROBERT. (AM). Special assistant to vice-president, manufacturing department, Ethyl Corp.
Torrington—BAKER, ROBERT STUCKEY. (C/S—J-M). Works manager, Torrington branch, American Brass Co.
Westport—WEBER, WILLIAM C. (R,C/S—A-M). Process engineer and director of technical data, The Dorr Co.
FLORIDA
Brewster—CHESSON, MAYWOOD W., JR. (J). Assistant flotation plant superintendent, American Cyanamid Co.
IDAHO
Wallace—RICHARDS, BENJAMIN STEPHENS, JR. (AM). Sales representative, explosives, E. I. du Pont de Nemours & Co.
ILLINOIS
Chicago—DALLMAN, ROBERT ADOLPH. (M). Metallurgist, Robert W. Hunt Co. HANSEN, MAX. (R—M). Associate professor, department of metallurgical engineering, Illinois Institute of Technology. WELLS, RALPH G. (AM). Metallurgist, Carnegie-Illinois Steel Corp.
Hillsboro—RULE, WILLIAM THOMAS. (J). Plant metallurgist, Eagle-Picher Co.
Oak Park—MAXSON, MARSHALL WHITNEY. (M). Chief process metallurgist, Carnegie-Illinois Steel Corp.
KANSAS
Lawrence—HAMBLETON, WILLIAM WELDON. (J). Instructor of petrography, University of Kansas.
Wichita—HADDOX, R. PUTNAM. (J). Junior exploitation engineer, Shell Oil Co. HELLAR, DONALD LOUIS. (M). Geologist, Sohio Petroleum Co. PARRIOTT, ROBERT BENEDUM. (R,C/S—J-M). Geological engineer, Stickle Drilling Co. TATLOCK, THOMAS ALBERT. (M). Production superintendent, J. H. Tatlock, Inc. ZOLLER, HENRY E. (M). President, Derby Oil Co.
LOUISIANA
Jennings—BROCK, DONALD MARSH. (M). District manager, Garrett Oil Tools, Inc.
New Orleans—RATLIFF, J. PAUL, JR. (C/S—J-M). Partner and manager, Rey Supply Co.
MASSACHUSETTS
Swampscott—MOORE, JAMES HENRY. (M). Director, metals research department, National Research Corp.
MICHIGAN
Ann Arbor—FREY, DONALD NELSON. (J). Research associate, department of engrg. research, University of Michigan.
Detroit—WIEDMAN, CARL S. (C/S—S-J). Research metallurgical engineer, Carboloy Co.
Ishpeming—ALLEN, ERNEST A. (AM). Geological technician, The Cleveland-Cliffs Iron Co.

MINNESOTA

Calumet—BOLITHO, WAYNE RUSSELL. (C/S—S-J). Assistant chief engineer, Inter-State Iron Co.

Coleraine—VANDELINDER, MARION DELBERT. (C/S—S-J). Mining engineer-trainee, Oliver Iron Mining Co.

Minneapolis — WARREN, ALICE ROCKWELL. (AM). Vice-president and secretary, Langdon-Warren Mines, Inc.

St. Paul—BATHKE, ALFRED SNYDER. (M). Partner, F. H. Bathke.

MISSISSIPPI

Laurel—BAKER, WILLIAM HENRY. (J). Drilling fluid engineer, Magnet Cove Barium Corp. CROWE, JESSE OVEL. (M). Assistant zone superintendent of production, production division, Gulf Refining Co. McGLOTHLIN, JOHN THOMAS. (M). Consulting geologist.

MISSOURI

Bonne Terre—JAMES ALLAN HARRIS. (C/S—J-M). Field geologist, St. Joseph Lead Co.

Columbia — FRAUNFELTER, GEORGE HENRY. (C/S—S-J). Graduate assistant in geology, University of Missouri.

Florissant—DESLODGE, BERNARD FARRAR. (AM). Geologist, Minerva Oil Co. DESLODGE, JOSEPH. (M). President, Minerva Oil Co.

Fredericktown—RIGGS, LAWRASON, III. (R,C/S—S-M). Business representative, Mine La Motte Corp.

Kansas City—NORQUIST, DONALD E. (M). Metallurgical sales, Sheffield Steel Corp.

NEW MEXICO

Carlsbad—JUHOLA, NEIL MATTHEW. (M). Acting mine foreman, Potash Co. of America.

Hobbs—LAMONT, NORMAN. (C/S—S-J). Trainee, Shell Oil Co.

Silver City—GRUNIG, JAMES KITCHELL. (J). Geologist, U. S. Geological Survey.

NEW YORK

Brooklyn—CUTLER, SEYMOUR S. (J). Plant manager, Standard Type Metals Corp.

Jamaica — GOODMAN, HERBERT HAROLD. (C/S—S-J). Metallographer, American Electro Metal Corp.

New York—FRIEDMAN, LOUIS T. (M). Head, department of metallurgical engineering, Sam Tour & Co.

Schenectady — BALDWIN, ELMER EDMUND. (C/S—S-J). Engineer, on rotating assignment, General Electric Co.

White Plains—LORCK, KARL. (M). Head, technical division, U.S.A. branch, Elektrokemisk A. S.

OHIO

Cleveland — KRONBACH, GEORGE EDWIN. (M). Senior metallurgist, Thompson Products, Inc.

Columbus—SMITH, WILLIAM HENKING. (J). Assistant geologist, Geological Survey of Ohio.

Middletown—ELLIS, CEDRIC DOUGLAS. (M). Assistant superintendent, Open Hearth, ISCOR.

Olmsted Falls—IVES, LEE EMMET. (R—M). President, Lee E. Ives, Inc.

Warren—WILLIAMS, JOSEPH OSCAR. (J). Open hearth metallurgist, Republic Steel Corp.

OKLAHOMA

Henryetta — TAYLOR, GENE KINNEY. (M). Vice-president in charge of operation, Ben Hur Coal Co.

Miami — NEAL, CHARLES AIMAN,

JR. (AM). Vice-president, Bells Wells Oil Co.

Moore—WILLIAMS, JAMES JUNIOR. (J). Junior engineer, petroleum production, Cities Service Oil Co. (Del.).

Norman—MADDOX, GAISER DAWSON. (R,C/S—J-M). Assistant professor, petroleum engineering, University of Oklahoma.

Oklahoma City — COOKE, JOHN THIEME. (R,C/S—J-M). Petroleum engineer, Sohio Petroleum Co. SCHEIRMAN, GENE LEWIS. (C/S—S-J). Junior exploitation engineer, Shell Oil Co. SVOBODA, FLOYD JOSEPH. (J). Rotary service, The National Supply Co.

Tulsa—AMSTUTZ, RAY W. (C/S—S-J). Junior petroleum engineer, Earlougher Engineering. DERRICK, A. M., JR. (R,C/S—S-J). Junior petroleum engineer, Stanolind Oil & Gas Co. MAUL, ROBERT VINCENT. (M). Chemical engineer, Stanolind Oil & Gas Co.

PENNSYLVANIA

Bethlehem — WAHL, WILLIAM GEORGE. (M). Geologist, Bethlehem Steel Co.

Bristol — SUTER, WILLIAM GUY. (C/S — S-J). College representative, John Wiley & Sons.

Clairton — SMITH, FRED R. (M). Superintendent, open hearth, Carnegie-Illinois Steel Co.

Groveton — MARSALKA, JOSEPH JEROME. (C/S—J-M). Research laboratory supervisor, Blaw Knox Co.

Hazleton — REESE, ANTHONY GEORGE. (M). Mining engineer, anthracite flood prevention project, Bureau of Mines.

McKeesport — EKHOLM, LAVERNE G. (C/S—J-M). Assistant chief metallurgist, Duquesne works, Carnegie-Illinois Steel Corp.

Philadelphia — DANDO, ELON E. (AM). Divisional sales manager, Aero Service Corp. LANSDALE, PHILIP THOMAS. (M). Metallurgist, Henry Disston & Sons.

Pittsburgh — DRIESSEN, MAXIMILIAAN GUSTAAF. (M). Consulting engineer, Heyl & Patterson, Inc.; Koppers Co. HAMMOND, JOHN A. (AM). Pittsburgh division manager, National Carbon Co. LOUGHREY, DANIEL RIPLEY. (M). Superintendent, open hearth & Bessemer, Jones & Laughlin Steel Corp.

Pottsville — WHAITE, RALPH HAROLD. (M). Mining engineer, Bureau of Mines.

SOUTH CAROLINA

Charleston — KEILEN, JOHN J., Jr. (C/S—S-M). Project leader, West Virginia Pulp and Paper Co.

SOUTH DAKOTA

Lead — RICE, ARTHUR JAMES. (C/S—J-M). Cost engineer, Homestake Mining Co.

TEXAS

Alice—COOK EDGAR LOYD. (J). District engineer, Arkansas Fuel Co.

Anna—WEST, GEORGE WILLIAM. (M). Petroleum engineer, Sinclair Prairie Oil Co.

Austin—BARNES, BYRON ARTHUR. (R,C/S — J-M). Petroleum engineer, Magnolia Petroleum Co.

Corpus Christi — MOORE, ALVAN AUGUSTUS. (M). Partner, Clark & Bus Moore Oil Well Servicing Co.

Dallas — OWENS, DENNIS EMORY. (AM). Superintendent, bottom hole

sample laboratory, Core Laboratories, Inc.

Delmita — BIRDWELL, WARRIE RUSSELL, JR. (J). Field engineer, Sun Oil Co.

El Paso — WASHBURN, ALWYN LOUIS. (AM). Co-owner, sales manager, Don A. Carpenter Co.

Ft. Worth—GROGINSKI, PHILIP S. (M). Engineer and geologist.

Hebbronville — McAFEE, ROBERT VANDERVEER. (R,C/S—S-J). Area engineer, Sun Oil Co.

Houston — DODD, JAMES GRADY. (M). Reserve geologist, Tennessee Gas Transmission Co. FORD, ROBERT DAVIS. (M). Public relations manager, Schlumberger Well Surveying Corp. KINLEY, JOHN CARY. (M). Engineer, M. M. Kinley Co. MORIAN, STANLEY COFFIN. (R,C/S — J-M). President and manager, Dixie Chemical Co. PALMER, ARTHUR BOWEN. (M). General manager, Sperry-Sun Well Surveying Co. PLAZA, JOSEPH BREWER. (AM). Reservoir engineer, division office, Stanolind Oil and Gas Co. TENNANT, JOSEPH ALLAN, JR. (M). Economist, Cameron Iron Works.

Lone Star—BOND, WILLIAM ROBERT. (M). Works manager, Lone Star Steel Co.

Midland — BLACKWOOD, JAMES COSBY. (M). Petroleum engineer, Amerada Petroleum Corp. HENDERSON, GEORGE HARVEY. (M). Electric well services supervision, Halliburton Oil Well Cementing Co.

Odem—BRADY, HAROLD JUDSON. (C/S—S-J). Petroleum engineer, Seaboard Oil Co.

Tyler—VOGENTHALER, THOMAS J. (C/S—S-J). Junior engineer, Schlumberger Well Surveying Corp.

UTAH

Salt Lake City—URQUHART, ROBERT DEAN. (M). Mining engineer, Utah Fuel Co.

Tooele — DAWSON, HARMEL ARTHUR. (C/S—S-J). Metallurgist, Combined Metals Reduction Co.

WASHINGTON

Spokane—LINDEMUTH, JACOB H. (M). General superintendent, Mead Works, Permanente Metals Corp.

WISCONSIN

Milwaukee — FOLEY, EDWARD JAMES. (M). Research metallurgist, Ladish Co.

WYOMING

Casper—FANSHAWE, JOHN RICHARDSON, 2nd. (M). Acting district manager, Rocky Mountains, Seaboard Oil Co. of Delaware.

ALASKA

Fairbanks—HELLERICH, GEORGE. (R,C/S — AM-M). Manager, Alaska dredge operations, Brinker-Johnson Co. LOFTUS, THEODORE ALBERT. (M). Superintendent, U. S. Smelting Refining & Mining Co.

BRITISH COLUMBIA

Salmo — STARCK, LOUIS PHILIP. (C/S—S-J). Assistant mill superintendent, Emerald tungsten project, Canadian Exploration, Ltd.

MANITOBA

Bissett—O'HARA, THOMAS ALAN. (C/S—S-J). Surveyor, San Antonio Gold Mines, Ltd.

Winnipeg—ALLAN, JOHN DONALD. (C/S—S-M). Chief geologist, Manitoba mines branch, Department of Mines and Natural Resources.

Kingston — HONE, ANDRE. (M). Head, physical metallurgy division, Aluminum Laboratories, Ltd.

SONORA

Moreno—SPLANE, JOHN L. (C/S—S-M). General superintendent, Cia. Minera de San Jose.

BOLIVIA

Huanuni — VAN RAADSHOOVEN, WILLEM HENDRIK. (J). Mining engineer, Empresa Minera "San Jose".

BRAZIL

Volta Redonda, Est. do Rio—BASTOS, EURICO ALVES FERREIRA. (J). Assistant engineer, open hearth department, Cia. Siderurgica Nacional.

CHILE

Concepcion—PAIDASSI, JEAN. (M). Professor of metallurgy, University of Chile.

VENEZUELA

Caracas — PIERCE, A. CHARLES. (C/S—S-J). Geologist II, Creole Petroleum Corp.

ENGLAND

London — TYLECOTE, RONALD FRANK. (C/S—JFA-M). Investigator, British Non-Ferrous Metals Research Association.

ICELAND

Reykjavik—TRYGGVASON, TÓMAS. (AM). Consulting geologist, University Research Institute.

SPAIN

Madrid — SOTO, AMADOR GONZALEZ. (C/S—AM-M). Laboratory chief, Iron & Steel Institute of Spain; chief professor of Metallurgy, Escuela Politecnica del Ejército.

SWEDEN

Saxdalen—WALLIN, KARL GUSTAF. (M). Manager, Saxberget mine, Aktiebolaget Zinkgruvor.

SWITZERLAND

Gerlafingen — MAGYAR, STEPHEN. (AM). Research engineer, Von Roll Iron Works, Ltd.

LIBERIA

Monrovia — IMMINK, THEODORE WERNARD. (M). Geologist, Liberia Mining Co.

NORTHERN RHODESIA

Mufulira—NORRIE, JAMES PETERKIN. (R,C/S—A-M). Consulting mining engineer, Roan Antelope and Mufulira Copper Mines, Ltd.

TANGANYIKA

Geita—STANSMORE, NORMAN WILLIAM. (M). Mill superintendent, Geita Gold Mining Co.

QUEENSLAND

Mt. Isa — S P R A T T, RICHARD NICHOLAS. (J). Staff geologist, Mt. Isa Mines.

Student Associates

Elected February 15, 1949

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Elected March 16, 1949

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Milton B. Harper...Va. Poly. Inst.
John R. Harris...Texas A&M
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Concentration of the So₂ Content of Dwight-Lloyd Sintering Machine Gas by Recirculation

W. S. REID,* Member AIME

In March, 1938, E. P. Fleming, metallurgist for the American Smelting and Refining Co. inaugurated an investigation into the possibilities of recirculating the gases from Dwight-Lloyd sintering machines operating on lead charge, with the twofold object of concentration of the SO_2 content and reduction in volume of total gas produced.

The possibility of recovering a commercial grade of SO_2 gas from D & L machines operating on lead charge had previously been considered by several investigators.

Early History of Recirculation

The Selby Smelter Commission Report, published by the Bureau of Mines in 1914, contains a chapter by A. E. Wells regarding results obtained at Selby, wherein some of the richer gas was recirculated through a hood over the pallets.

Oldright and Miller of the U. S. Bureau of Mines had also made tests at Trail, B.C., and at Kellogg, Idaho.

R. C. Rutherford, while at the Chihuahua, Mexico, Smelter of the American Smelting and Refining Co., in May, 1937, proposed recirculation of D & L gases to decrease the volume of gas handled by the baghouse.

At none of these plants, however, was the operation commercialized.

In July, 1938, Mr. Fleming, in correspondence with the Selby Plant, inquired regarding the possibility of obtaining 6 pct SO_2 gas from the Selby D & L machines.

At that time, the writer advised that there was slight possibility of obtaining 6 pct SO_2 gas without re-

circulation, but believed that it was possible with recirculation, and that experimental work toward that end should be tried at some plant where spare D & L machines were available.

The foregoing statement was based on the following information then available—

1. Tests on Selby first-over machines showed 2.28 pct SO_2 from first windbox and 1.03 pct SO_2 from second windbox, and corresponding figures for second-over charge of 0.81 pct SO_2 for first windbox and 0.08 pct SO_2 for second windbox.

2. Oldright and Miller (U.S. Bureau of Mines) in 1932 at Bunker Hill, on 42 in. $\times$ 22 ft machines found:

    a. First-over charge—Maximum SO_2 concentration (leaving cake) of 9.5 pct.

    b. First-over charge—SO_2 concentration of over 8 pct from the 4 ft to the 12 ft points beyond the front deadplate and that the concentration then dropped rapidly.

    c. That approximately 80 pct of the total sulphur eliminated on the second-over machines occurred during the travel of the pallets from the 1 ft to the 6 ft distances from the deadplate.

    d. That approximately 94 pct of the total sulphur eliminated on the second-over machines occurred over the first windox.

3. Oldright and Miller (U.S. Bureau of Mines) in 1932, at Trail, on 42 in. $\times$ 50 ft machines found:

    a. First-over charge—SO_2 varied
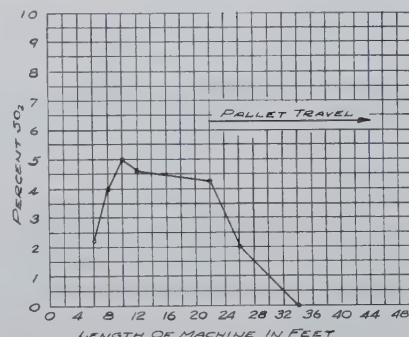
FIG 1—Sulphur elimination curve.

from 2.0 pct to 5.5 pct (leaving cake) from the 12 ft to 28 ft points from the deadplate.

b. That the average SO_2 increased from 1.0 pct at 7 ft from deadplate to maximum of 3.3 pct at 20 ft, then dropped to 1.5 pct at 40 ft.

c. That on a 22 ft, second-over machine with an 11 in. bed the SO_2 varied from 4.5 pct to 6.5 pct from the 2 ft to the 8 ft points from the deadplate.

d. That on the final roast, the SO_2 concentration also varied across the pallets; that is, $2\frac{1}{2}$ pct at the side, increasing to 6.0 pct, 5 in. in, and to 7.0 pct at 10 in. to 20 in. in, then decreased vice versa at the opposite side.

e. Concluded that most of the sulphur on a 22 ft machine was removed over the first 7 ft of the first windbox; therefore, they partitioned the first windbox so that the exit gas from the second 4 ft section was returned to the surface of the pallets over the first 7 ft section, and during a seven-day trial the gas from the 4 ft section averaged 2.4 pct SO_2, while the recirculated gas from the first 7 ft section only increased to 3.8 pct SO_2. (Excess suction over the 7 ft section to prevent escape of SO_2 laden gas from the 4 ft section caused dilution by air.)

f. That recirculation had the advantage of filtering out the dust contained in the recirculated gas.

g. That second-over charge on a 50 ft machine gave SO_2 concentrations ranging from 2.4 pct at 6 ft to 4.0 pct at 8 ft; to 5.0 pct at 10 ft, to 4.6 pct at 12 ft; to 4.3 pct at 22 ft; to 2.0 pct at 26 ft; to 1.0 pct at 30 ft; to trace at 34 ft from deadplate.

If the figures under *g* are plotted, we have what is now known as a sulphur elimination curve, which is shown in Fig 1.

Preliminary Work at Selby

At the Selby, Calif., Plant of the American Smelting and Refining Co., the company, since 1937, had been operating a 40-ton per day Contact Acid Plant on gases from the roasting of pyritic gold concentrates on a seven hearth Wedge Roaster. This conversion of SO_2 to H_2SO_4 was beneficial in reducing the output of SO_2 from the smoke stack.

At that time (1938) some consideration was also being given to the construction of a liquid sulphur dioxide plant to utilize still more of the SO_2, normally exhausted through the stack.

During Sept., 1938, the first investigation was made at Selby in connection with the feasibility of obtaining a good grade of SO_2 gas from the D & L machines.

Holes were drilled in the sides of various pallets in such a manner that a sample pipe could be inserted to the center of the bed, just under the grate bars. Gas samples taken through the pipe, as the pallets passed over the windboxes, were then analyzed for SO_2.

These first tests on a 42 in. × 22 ft D & L machine, operating with a 4-in. bed at a pallet speed of about 29 ipm, 25 to 30 pct return sinter on a very fine charge, with windbox suction at 12 in. to $12\frac{1}{2}$ in. H_2O, fan volume at 17,500 cfm, and sulphur in charge reduced from 13.0 pct to 5.3 pct, showed as follows for the first windbox:
Pct SO_2 under grates—4.6 pct to 9.2 pct—Average—7.4 pct
Pct SO_2 leaving windbox—1.1 pct to 1.35 pct—Average—1.25 pct

It was obvious that the principal source of air leakage was between the pallets and the windbox and over the deadplates, with smaller amounts through the shrinkage fissures at the junction of the sinter cake with the side of the pallet, between the pallet
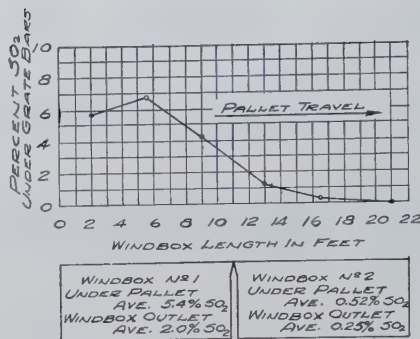
FIG 2—First-over charge—12 pct sulphur.
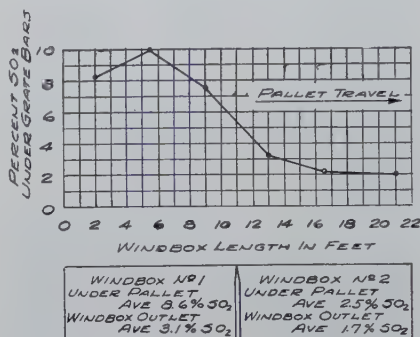
FIG 3—Second-over charge—4.5 pct sulphur.

ends, and around windbox cleanout doors, and the like.

The second windbox on the same charge showed SO_2 concentrations under the grates varying from 6.5 pct to 10.0 pct, and averaging 7.8 pct.

These tests indicated that on this very tight charge, the sulphur elimination continued high throughout the length of machine.

Tests were then made on a second-over machine, operating with a $5\frac{1}{4}$ in. bed at 19 ipm speed, with windbox suction at $6\frac{1}{2}$ in. H_2O, and fan at 15,000 cfm. These tests showed peak sulphur elimination about midway of the first windbox, after which it dropped rapidly as the pallets passed to and across the second windbox.

A typical set of SO_2 readings showed 2.3 pct SO_2 at the 2 ft mark, a peak of 5.5 pct midway of the first windbox, then decreasing amounts to the second

windbox, which averaged only 0.15 pct for its entire length. It was evident that the first windbox was doing about 90 pct of the work as far as actual sulphur elimination was concerned. The second windbox was serving, principally, as a cooler for the hot sinter cake.

These preliminary tests clearly indicated that, in order to secure a good grade of SO_2 gas, it would be necessary to recirculate the intermediate grade gas through hoods covering the entire pallet including ends and the sealing strip, and collect the concentrated gas from a relative short section of the machine where the SO_2 concentration was highest.

Preliminary Work at Murray

Further experimental work along the lines of Mr. Fleming's suggestion was performed under the supervision of Mr. A. L. Labbe at the Murray, Utah, Plant of the American Smelting and Refining Co. This work was started in Nov., 1938, on standard 42 in. × 22 ft D & L machines on both first-over and second-over charge. By taking gas samples from 2 in. below the grate bars as the pallets passed over the windboxes, the SO_2 concentrations at various points along the machine were determined.

Fig 2 shows, in graphic form, the resultant data for a "first-over" charge and Fig 3, the same for a "second-over" charge.

These graphs illustrate how the SO_2 concentration increases to a peak about midway of the first windbox and then rapidly decreases as the pallets proceed to and over the second windbox.

The comparison of strength of gas under the pallets vs. strength of gas in the outlet from the windbox brings out the often overlooked fact that an unbelievably high leakage of air occurs under and around the pallet ends and over the deadplates. The following tabulation, based on the foregoing data, might demonstrate more clearly this high leakage factor of the ordinary D & L machine:

	First Windbox			Second Windbox		
	Pct SO_2 Under Grates	Pct SO_2 Leaving Windbox	Pct Air Leakage	Pct SO_2 Under Grates	Pct SO_2 Leaving Windbox	Pct Air Leakage
First-over Charge	8.6	3.1	277	2.5	1.7	147
Second-over Charge	5.4	2.0	270	0.52	0.25	208

Or, for the machines as a whole:

First-over Charge—231 pct air leakage

Second-over Charge—263 pct air leakage.

Later tests on varying charges, depths of bed, and others, indicated air leakages varying up to 400 pct.

Recirculation at Murray

In March, 1939, the first actual recirculation of gases at Murray, Utah, was tried out on a standard 42 in. × 22 ft D & L machine. This initial installation consisted of a recirculation fan, which delivered the gases from the second windbox through a duct to a hood over the pallets on the first windbox. On a firstover charge, carrying 11.0 pct S, it effected an SO_2 concentration averaging 5.1 pct SO_2 in the reduced volume of gas delivered to the Cottrell flue. However, this final gas varied from 4.0 pct SO_2 to 6.5 pct SO_2, depending on variations in the moisture content and uneven porosity of the bed. The uneven porosity was due principally to segregation of coarse and fines in the charge hopper above the machine.

This first trial installation also demonstrated the importance of a baffle plate over the windbox partition to minimize the interchange of the weak and strong gases, and, likewise, the partitioning of the conventional windboxes, or construction of different sized windboxes to obtain the maximum concentration of the SO_2.

To summarize, this first trial installation effected the following on first-over charge:

Gas volume reduced from 19,000 cfm to 6,850 cfm.

SO_2 concentration in final gas increased from 1.7 pct to 5.1 pct.

At this time, it was realized that the same proportional decrease in volume would not be possible from a wider machine because the volume resulting from side leakage is approximately the same regardless of the width of the machine.

This initial installation at Murray is still in service, but utilized solely to decrease the volume of gas going to the Cottrell treaters.

Patent

Based upon data obtained on this preliminary work, Mr. Labbe applied

FIG 4—Data obtained over 5-day period on a first-over charge averaging 10.5 pct S.

for, and was subsequently granted, U. S. Patent No. 2,235,261, entitled, "Method and Apparatus for Sintering."

Prior commercial applications of utilizing the oxygen content of weak gas for additional roasting, or in effect further concentration of the SO_2 content of these gases, had accomplished their purpose by returning the weak gases from the last windbox to a closed hood over a limited central section. Attempts on a two-windbox machine to return the gases to a hood confined over the sinter bed of the first windbox had failed, due to the SO_2 in the circulated gases smothering the combustion in the sinter bed proper.

The main features of the sintering machine of Mr. Labbe's patent may be summarized as follows:

Although it is applicable to multiple windbox machines, its application to a two-windbox machine is described merely for simplification.

A hood is provided over most or all of the bed, including pallet ends and wheels, over the second windbox and a large proportion of the first windbox. It cannot be extended any farther over the first box on account of the ignition muffle. The hood also extends over the discharge end of the machine.

There are no cross-sectional baffles in the hood to confine the direction of the smoke to any one portion of the sinter bed. The smoke is free to establish its own course or equilibrium over the entire surface of the sinter bed. Part of the circulated smoke may be drawn back through the same bed of the second windbox.

An inner hood with an opening adjacent to the ignition muffle extends back under the recirculation hood proper, for a distance, over the sinter bed of the first windbox. This allows some outside air to enter and freely support combustion, yet diverts the

recirculated gas around the ends of the pallets and thus substitutes this SO_2 laden gas for the air that is ordinarily drawn in as leakage on an unhooded machine.

Trial Recirculation at Selby

By Sept. 1939, the D & L machines at Selby had been enlarged, the sintering practice improved and serious consideration was being given to the utilization of D & L gases for the production of liquid SO_2.

As a result, a new series of tests were made on the gases by taking samples from under the grate bars by inserting a sample pipe through holes near the top of the various windboxes. A sulphur elimination curve depicting the average data obtained over a 5-day period on a first-over charge averaging 10.5 pct is shown in Fig 4.

While this sulphur elimination curve showed a 15-ft section of the machine producing better than a 5 pct concentration of SO_2, the actual SO_2 concentration leaving the windboxes averaged only 2.1 pct. This indicated a high infiltration of air around windbox seals, between the pallets at the side of the machine, over the deadplates, and through the shrinkage space between the bed and sides of the pallets.

This machine was reducing 200 tons of charge from 10.5 pct S to 4.5 pct S per day with the fan handling a volume of 25,000 cfm at 440°F.

Gas concentration from the windboxes varied widely, depending on the nature of the charge. A tight charge increased the air leakage, thereby decreasing the SO_2 content of the gases leaving the windboxes. Variations in the depth of the bed on various machines resulted in SO_2 concentrations varying from 0.6 pct to 2.32 pct.

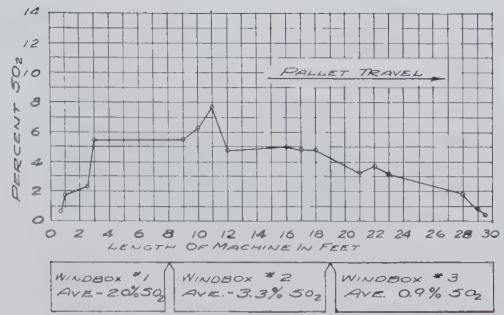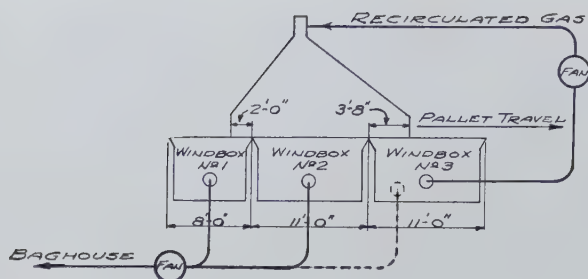The first trial recirculation unit at

FIG 5—Recirculated gas.

Selby was completed and put into service on May 10, 1940, and consisted of a No. 9 Type P. B. American Blower Co. Exhauster Fan for concentration of the SO_2 content of the gas from a three-windbox D & L machine, 42 in. wide × 30 ft long, operating on "first-over" charge.

The design for this recirculation unit, including the location of the hoods, was based upon the sulphur elimination curve for the average charge handled by the machine. The so-called sulphur elimination curve, or a knowledge of the data from which it might be drawn, is fundamental in designing a recirculation unit. The pattern varies with different sized machines and with variations in the charge on the same sized machines.

The sulphur elimination curve of a machine on "first-over" charge is quite different from the same sized machine or "second-over" or final charge.

The procedure which has been developed for making a sulphur elimination curve is as follows: 1. Have D & L machine operating normally, with uniform feed.

2. Determine SO_2 content of gases directly under the grate bars at intervals throughout the passage over the windboxes.

Under (1) it is important that the charge be uniform as to analyses, size and moisture content, as well as being uniformly laid down on the pallets. Uniformity of material on the pallets is of major importance because it is impracticable to take and determine gas samples from numerous points throughout the length of the machine simultaneously. As the gas samples must be taken progressively, it is obvious that conditions must be comparable during the entire sampling period. Particular care should be exercised to prevent major segregation of coarse and fines in the feed hoppers

over the machine, yet at the same time obtain a uniform segregation of coarse and fines as the charge is laid down on the pallets. This last mentioned condition is secured by proper design of the feeding mechanism and close control of the talus pile. A high talus pile usually causes "sloughing" which results in a spotty bed, while a "low" talus pile tends to "break" the segregation, which is so desirable at this point.

Under (2) the actual data for plotting the sulphur elimination curve is obtained by sampling the gas directly under the grate bars. In actual practice, these samples are now taken by inserting a curved pipe through openings near the top of the windboxes, allowing same to follow the travel of the pallet a sufficient length of time to draw a measured volume of gas sample through an iodine solution for analysis. In this manner, a sample is obtained which is undiluted by the enormous air leakage normally occurring under and around the ends of the pallets. By taking several of the samples at each location, the average SO_2 concentration at this particular point may be determined and from this a sulphur elimination curve may be plotted.

This first recirculation unit at Selby was entirely for experimental purposes as no utilization of the concentrated gas was made.

The first-over machines at that time were delivering up to 28,000 cfm of approximately 1.5 pct SO_2 gas to the baghouse. This grade of gas was entirely too low in sulphur dioxide to maintain the conversion temperatures at the Contact Acid Plant.

The 42 in. machine equipped for this experimental work had three windboxes, the first box being 8 ft long and the second and third boxes, 11 ft each. The gas from the No. 3 box was returned by the recirculation

fan to a hood over part of No. 1 box and all of No. 2 box, as indicated in Fig 5.

It was soon learned that maintaining proper balance of draft in the recirculation hood was essential. Actual pressure in the recirculation hood caused a smoke nuisance in the building. Excess draft permitted infiltration of air and resultant dilution of the concentrated gas. A definite drop in the concentration was noted whenever the draft in the recirculation hood exceeded 0.02 to 0.03 in. water. This precise regulation was later accomplished by the installation of a damper controlled by a Bristol free-vane controller. Recording draft gauges were also installed in the various windboxes and an SO_2 recorder installed to indicate and continuously record the SO_2 concentration in the concentrated gas.

On the first-over charge, averaging about 13.0 pct S, the recirculation fan handled a volume of 5,000 to 9,000 cfm at temperatures ranging from 700 to 800°F.

By close attention to all operating details, it was demonstrated that with the high sulphur charge being handled at that time gas concentrations of 6 to 8 pct SO_2 could be obtained, but that with this degree of concentration the speed of the machine was reduced about 10 pct in order to effect the same overall sulphur elimination. Overall gas volume to the baghouse with recirculation was approximately 11,800 cfm at 385°F, as compared to approximately 23,100 cfm at 330°F without recirculation. Subsequent improvements in the windbox, duct, and hoop designs corrected this loss in tonnage feature. The first step was to by-pass part of the gas from Windbox No. 3 to the main fan, as indicated by the dotted lines in Fig 5. This practically doubled the suction in Windbox No. 3 and equalized it with No. 1 and No. 2 Windboxes.
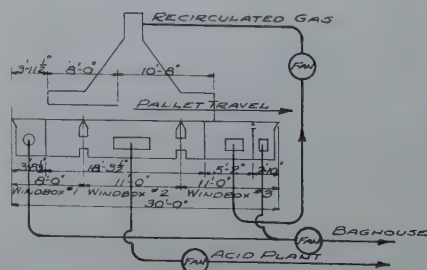

FIG 6—Schematic diagram of first-over recirculation.

These preliminary tests, along with the sulphur elimination curve of the machine indicated that the installation of partitions in the first and third windboxes, whereby the weak gas from the end sections could be segregated and by-passed direct to the baghouse, would be advisable. These tests also showed that when recirculating approximately 3,000 cfm the total fan power consumed was about 69 hp, as compared to 60 hp with the machine operating normally, that is, without recirculation.

During April, 1942, an improved recirculation system for the first-over machine at Selby was completed and further tests proceeded. This new installation consisted of a recirculation fan which drew the recirculated gases through a series of vertical pipe coolers before returning them to the hoods over the pallets. This cooler was later abandoned. The windboxes were also subdivided.

Fig 6 shows a diagramatic flow sheet of the gases and sizes of various windboxes.

This layout demonstrated that when handling a raw feed mix, averaging 12 pct S, the machine would produce an average of 5,900 cfm at 310°F, of 7.0 pct SO_2 gas for possible utilization at an acid or SO_2 plant.

The concentration of SO_2 varied with the charge, depending largely on the physical characteristics and also on the proportion of sulphide sulphur in the raw feed. Sulphur present as pyrite, for example, was much more desirable than a charge in which part of the sulphur was present as sulphate. Low SO_2 in the concentrated gas invariably accompanied high volume and vice versa. For example:

7.0 pct SO_2 (20 tons S per day)— Volume, 6,400 cfm at 250°F
8.75 pct SO_2 (16 tons S per day)— Volume, 5,200 cfm at 330°F
Volume of the recirculated gas varied with the charge between limits as follows:
4.0 pct SO_2—3,500 cfm at 400°F
7.0 pct SO_2—1,500 cfm at 300°F
The distribution of volumes was roughly as follows:

	Cfm
First Windbox (4 ft long)......	3,000
Middle Windbox (concentrated gas).....................	5,900
Recirculation Windbox (net)...	1,500
Last Windbox................	3,500
Main Bustle Pipe and Fan Leakage.....................	1,100
Total Volume at Main Fan....	15,000 at 375°F and 4.5 pct SO_2

Leakage between the deadplate and the pallets was largely accountable for the high volumes from the end windboxes.

Test runs over a period of months on this machine indicated that, with a charge averaging about 11.0 pct S, it was possible to produce approximately 6,300 cfm of 7.0 pct SO_2 gas, leaving the middle windbox. This amounted to about 18.8 tons of S per day, or sufficient to produce around 50 tons of H_2SO_4 per day.

Commercial Recirculation at Selby

By the middle of 1942, the War Production Board's famed Order L-208 had seriously curtailed the production of pyritic gold concentrates from the California gold mines. High sulphur concentrates, formerly received in excess of the capacity of the one Wedge roaster at Selby dwindled to the point where lower sulphur concentrates containing lead and zinc had to be substituted in order to keep the 40-ton per day Contact Sulphuric Acid Plant supplied with SO_2 gas. However, the gradually decreasing receipt of pyritic concentrates was acutely curtailing the production of sulphuric acid, which was a critically needed war supply. Barren pyrite was even being used at a loss to enrich the Wedge charge.

As a result of the urgent need for sulphuric acid and based upon the favorable results obtained on the experimental recirculation unit on the D & L machine, an appropriation request was filed in Aug. 1942, to equip a second machine with a recirculation unit and to collect and convey the concentrated gases from both machines to the sulphuric acid plant.

This application was made during the height of difficulties in obtaining priority ratings from the War Production Board. However, after much red tape, preparation of minutely detailed lists of materials, substitutions of used motors, and other procedures, an A-1-A Rating was finally obtained and the work got under way, late in 1942.

Wartime delays in delivery of materials and equipment postponed completion of this unit until March 8, 1943.

The D & L gas was at first mixed with the Wedge gases, but after 26 hr operation it was apparent that special conditioning of the D & L gases would be required in order to recover any appreciable amount of the solids in the Cottrell treater through which the Wedge gases had previously been treated.

Conditioning equipment, consisting of water sprays, and SO_3 gas, direct from the Acid Plant, was installed in the distribution chamber ahead of the Cottrell (Plate) Treater and considerable work done in closing up leaks in the Cottrell unit and the flue system.

For the next three months, the Acid Plant alternated periodically from D & L to Wedge gases as various operating "bugs" were discovered and corrected.

Starting on July 26, 1943, the Acid Plant operated regularly on D & L gas from first-over machines with the Wedge utilized merely as a standby unit to keep the Acid Plant going during occasional periods when the Sinter Plant was shut down.

Since that time, the 40-ton per day Contact Acid Plant has continued to operate on D & L gases concentrated by recirculation.

Sulphuric acid made from SO_2 gases originating from a straight pyritic concentrate roasted in a multiple hearth roaster is normally water-white in color. However, when the supply of pyritic gold concentrates began to dry up and complex flotation concentrates were substituted, it was noted that the resultant sulphuric acid was, at times, discolored, and with greater percentages of the complex concentrates on the charge the acid was close to a coffee-brown in color.

It is believed that this color imparted to the sulphuric acid is caused by hydrocarbons originating from flotation reagents which carry through the scrubbing towers, mist precipitators and coke filters to the drying tower, where they are picked up by the drying acid and act as a dye to all acid produced.

The colloidal carbon imparting the color is so finely divided that no settling as a sediment ever takes place. It is more in the nature of a dye, and in no way lowers the purity of the acid or decreases its usefulness in the normal commercial uses to which it is put. However, as this discoloration is objectionable to certain customers, particularly the food processing plants, it was deemed desirable to clarify the product and a method for so doing has been devised by Mr. Walter F. Johnson, Research Dept. metallurgist.
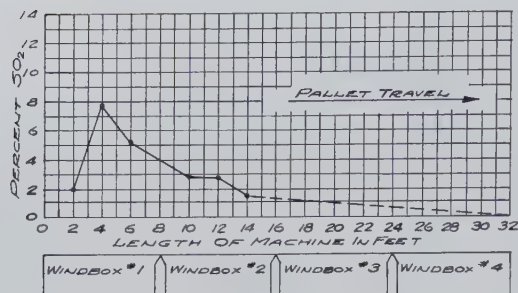
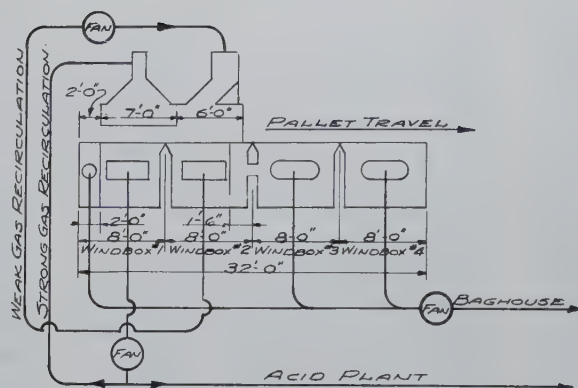FIG 7—Sulphur elimination curve showing typical graph of data obtained.

FIG 8—Schematic diagram of second-over recirculation.

In May, 1945, a new recirculation system on a 63 in. × 32 ft, "second-over" D & L machine was completed. This unit consists of two 10,000 cfm fans, hoods, ducts, control instruments, and other items.

This installation was made for the threefold purpose of (1) obtaining practical operating data on second-over charge; (2) supplemental SO_2 supply for the acid plant; and (3) SO_2 supply for a liquid sulphur dioxide plant to be constructed at some future date.

Prior to designing the recirculation unit for this 63 in. second-over or Final Product Machine, numerous tests were made to determine the sulphur elimination characteristics.

The sulphur elimination curve in Fig 7 shows a typical graph of the data obtained.

It will be noted that this sulphur elimination curve is quite different from the curve for a machine handling first-over charge.

Here, after the charge is ignited, the bed roasts rapidly, coming to a peak about midway of the first windbox

and then tapering off rapidly over the second windbox. Very little sulphur is eliminated over the third windbox and practically none over the fourth or last windbox.

Fig 8 shows the windbox and hood design for this machine and a diagrammatic outline of the flow of gases.

Following a preliminary test period, the concentrated gases from this machine were diverted to the Acid Plant on June 18, 1945, and have been utilized periodically since that time to supplement the concentrated gases from the first-over machines.

At the present time, the concentrated gases from the second-over machine are actually higher in SO_2 content than those from the higher sulphur first-over charge.

In Sept. 1947, a 15-ton per day liquid sulphur dioxide plant was completed at Selby and, since that time, both the sulphur dioxide plant and the sulphuric acid plant have been operated entirely on D & L lead charge gases, concentrated by recirculation.

The sulphur dioxide plant is not dependent on a certain grade gas, as is

the contact acid plant. It will function on any strength gas from the roasters and operates smoothly and efficiently on the 5 to 6 pct SO_2 in the gases normally produced by the recirculation units on the Dwight-Lloyd machines.

The SO_2 plan is a patented process,* developed by the American Smelting and Refining Co. Research Dept., under the able direction of Mr. E. P. Fleming. It functions by the absorption of SO_2 in dimethylaniline flowing counter current to the gas stream in a tower consisting of a series of bubble-cap trays. The pregnant D.M.A. solution then goes to a stripping tower where the SO_2 is expelled by boiling with steam heated calandrias. The wet SO_2 gas is dried by passing through sulphuric acid in a third bubble-cap tower, then compressed to liquid and transferred to storage tanks from which the entire production is shipped in railroad tank cars.

The Crystal Structure of Ni₄W

E. EPREMIAN* and D. HARKER†

THE constitution of the nickel-tungsten system has been studied by a number of investigators, the most recent of which are Ellinger and Sykes.[1] On the basis of metallography, electrical resistivity and hardness measurements and some X ray diffraction work, they constructed a consitution diagram (Fig 1). Ellinger and Sykes report a_0 for the alpha face-centered cubic phase (nickel saturated with tungsten) as 3.66Å.‡ The gamma phase (tungsten saturated with nickel) is given as body-centered cubic, but no value of a_0 is recorded. At 43 pct tungsten by weight (approximately 20 at. pct) a beta phase is reported, but structure and lattice parameter are not known. Primarily on the basis of metallographic evidence, they conclude that beta is a new phase and rule out the possibility of formation of a superlattice since they observe a new phase in the microstructure.

Grube and Schlecht[2] report an ordering reaction in a system similar to the Ni-W (Ni-Mo) and Harker[3] has shown that Ni₄Mo forms a superlattice upon the pre-existing face-centered cubic lattice of the alpha phase. Ellinger and Sykes observed a change in the diffraction pattern of a 43 pct W alloy upon aging and attributed it to the formation of a new phase.

Thus, there appears to be some question as to the character of the beta phase reported by Ellinger and Sykes. The purpose of the present work is to determine precisely the structure and nature of the beta phase in the Ni-W system of X ray diffraction methods.

Experimental Procedure

One inch diameter ingots of 43.66

‡ Distances are reported in true angstrom units throughout this work. Distances in kX must be multiplied by 1.00202 to give distances in angstroms.
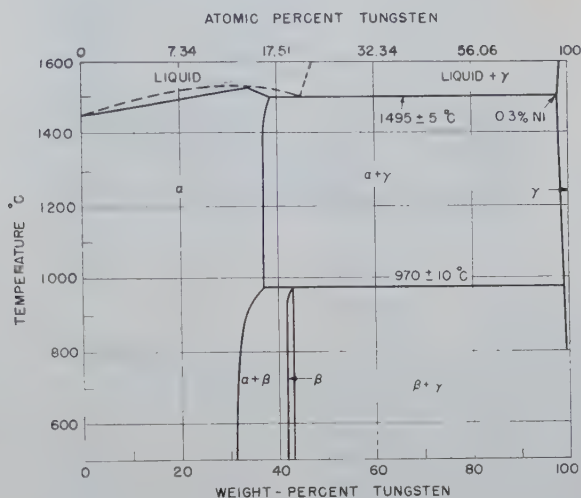
FIG 1—Constitution diagram of the nickel-tungsten system after Ellinger and Sykes.

pct, 40.15 pct and 34.06 pct tungsten by weight (19.8, 17.6 and 14.1 at. pct respectively) were melted and cast under vacuum from electrolytic nickel and pure wire filament grade tungsten. The ingots were soaked for 16 hr at 1300°C in a hydrogen atmosphere furnace, then swaged at this temperature and finally drawn to 0.020 in. diam wire. Some of the bar stock was retained in ½ in. diam rod for hardness and metallographic studies. Wire samples for diffraction work were sealed in evacuated quartz tubes and subjected to the various solution and aging heat treatments in a hydrogen

furnace. X ray photograms were taken in a Debeye-Sherrer camera using copper K radiation filtered by nickel foil.

Results

X RAY DIFFRACTION

The lattice parameters of the alpha and gamma phases at saturation were determined by an X ray photogram of the 19.8 at. pct W alloy after solution heat treatment at a temperature well within the alpha-gamma range above the peritectoid temperature (17 hr at 1150°C—oil quenched). The alpha phase was found to be face-centered cubic with a_0 of 3.594 ± 0.001Å, while the gamma phase was determined as body-centered cubic with a_0 of 3.158 ± 0.001Å. Exactly the same phases and parameters were obtained with the 17.6 at. pct W alloy for the same solution heat treatment.

Thorough analysis was made of an X ray photogram of a 19.8 at. pct alloy sample in the quenched and aged condition (solution treated 17 hr at
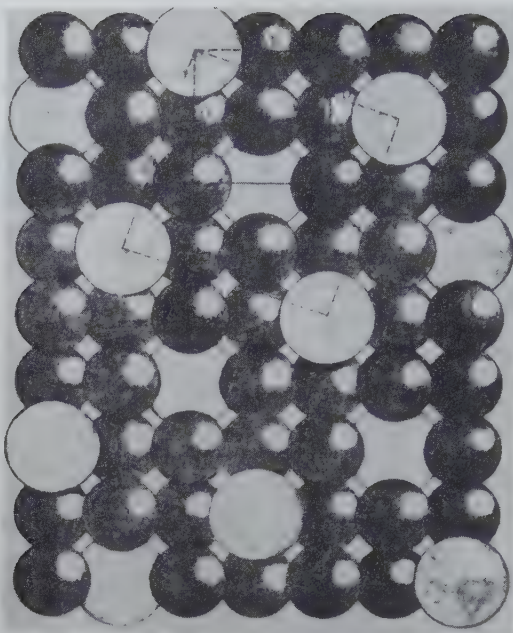
FIG 2—View of the structure of Ni_4W along [001].

1150°C—oil quenched; aged 65 hr at 950°C—oil quenched). An attempt was made to index the lines of the pattern on the basis of a tetragonally distorted face-centered cubic unit cell, but it was found that all of the new lines could not be accounted for. The lattice parameters of the small tetragonal unit cell were determined to be $a_0 = 3.6248 \pm 0.001$ and $c_0 = 3.553 \pm 0.001$Å with $c/a = 0.980$.

It was necessary to choose a large tetragonal unit cell in order to assign indices to all of the lines appearing in the pattern. The dimensions of this unit cell are $a'_0 = 5.730 \pm 0.001$ and $c'_0 = 3.553 \pm 0.001$Å with

$$c/a = 0.620.$$

The structural relationship between the two cells is shown in Fig 2. The following equations relate the indices of the small cell to those of the true large cell. (Primed indices refer to the new large cell):

$$h' = \frac{3h - k}{2}$$

$$k' = \frac{h + 3k}{2}$$

$$l' = l'$$

The volume of the large cell is 2.5 times the volume of the small tetragonal cell, $a'_0 = \left(\frac{5}{2}\right)^{\frac{1}{2}} a_0$ and $c'_0 = c_0$.

Those lines which could be indexed on the basis of the small unit cell have indices for which $2h' + k'$ or $h' + 2k'$ is a multiple of 5. These lines, which are quite sharp and strong, make their appearance by splitting from the lines of the alpha face-centered cubic phase.

The lines were indexed by making use of the relation $Sin^2 \theta = A(h^2 + k^2) + B(l^2)$ where A and B are constants involving the lattice parameters and wave length (from $Sin^2 \theta = \frac{\lambda^2}{4}\left[\frac{h^2 + k^2}{a^2} + \frac{l^2}{c^2}\right]$). This relation was applied to the $Sin^2 \theta$ values for several low order planes whose hkl indices were known with certainty to predict the $Sin^2 \theta$ values for planes with higher indices. The A and B values were fitted with the observed data and the lines indexed. These lines which were newly assigned indices were in turn used to index planes of still higher order, the process being repeated until all of the lines were identified. This method gives a self-consistent solution to the data, and automatically provides accurate values of the lattice parameters at values of θ (the Bragg angle) near 90°. It was found that $h + k + l$ for all planes was even, which indicates that the structure is body centered. Table 1 summarizes the results obtained for the ordered structure.

Since the unit cell of Ni_4W is body-centered, and since there are 2 W atoms and 8 Ni atoms in a unit cell, there are three possibilities for the space group of the ordered structure, which are as follows (in the notation of [5]):

1. $S^2_4 - I\bar{4}$: 2W in 2 (a)
             8Ni in 8 (g)
       parameters x,y,z

2. $C^5_4 - I$ 4: 2W in 2 (a)
             8Ni in 8 (c)
       parameters x,y,z

3. $C^5_{4h} - I$ $4/m$: 2W in 2 (a)
             8Ni in 8 (h)
       parameters x,y

All of these structures have the same projection on the x,y plane, but differ in the projection on the z-axis.

Intensity calculations were made to determine which of the three possible space groups correspond to the structure of Ni_4W. The relative intensities of lines were calculated by means of the following formula:

$$I = Constant \ x \ \frac{1 + Cos^2 2\theta}{Sin^2 \theta \ Cos \theta} P_{hkl}F^2_{hkl}A_\theta$$

$\frac{1 + Cos^2 2\theta}{Sin^2 \theta \ Cos \theta}$ is the Lorenz and Polarization Factor

    P_{hkl} is the multiplicity factor
    F^2_{hkl} is the structure factor
    A_θ is the absorption factor
    θ is the Bragg angle

Since the ordered structure is formed primarily from the alpha face-centered phase, it appeared likely that the atoms would be in an arrangement which is nearly that of cubic close packing. In this case, the approximate positions of the 10 atoms in the unit cell are as follows:

W at $xyz = 000$ and $\frac{1}{2}\frac{1}{2}\frac{1}{2}$
Ni at $xyz = \frac{1}{10}$ $\frac{3}{10}$ $\frac{1}{2}$; $\frac{2}{10}$ $\frac{6}{10}$ 0;
              $\frac{3}{10}$ $\frac{9}{10}$ $\frac{1}{2}$; $\frac{4}{10}$ $\frac{2}{10}$ 0;
              $\frac{6}{10}$ $\frac{8}{10}$ 0; $\frac{7}{10}$ $\frac{1}{10}$ $\frac{1}{2}$;
              $\frac{8}{10}$ $\frac{8}{10}$ 0; $\frac{9}{10}$ $\frac{7}{10}$ $\frac{1}{2}$.

and the space-group is $C^5_{4h} - I$ $4/m$. It is seen that half of these atomic positions are merely lattice translations of the others. Thus, the approximate positions are:

W at 000

Ni at $\frac{2}{5}$ $\frac{1}{5}$ 0; $\frac{1}{5}$ $\overline{\frac{2}{5}}$ 0; $\overline{\frac{2}{5}}$ $\overline{\frac{1}{5}}$ 0; $\overline{\frac{1}{5}}$ $\frac{2}{5}$ 0, that is, at $\frac{2}{5}$ $\frac{1}{5}$ 0 and positions derived from this by operation of the four-fold axis.

The structure factor formula for I $4/m$ is:

$$F_{hkl} = 2\{f_W + 2f_{Ni}[Cos \ 2\pi(hx + ky) + Cos \ 2\pi(kx - hy)]\}$$

where f_W is the atomic scattering factor for tungsten
    f_{Ni} is the atomic scattering factor for nickel
    hkl are the indices of the plane
    xy are the coordinates of one of the Ni atoms.

Using the above structure factor formula in the equation for intensity, and properly taking into account the change in atomic scattering factor, Lorenz factor, and absorption factor with change in the Bragg angle, the intensities of all the lines were calculated. Table 1 includes a comparison between the observed and calculated intensities of the lines for $x = 0.400$,

$y = 0.200$. Complete intensity calculations were made in which x and y were varied in steps of 0.005 between 0.390 — 0.410 and 0.190 — 0.210 respectively. The best agreement was obtained for $x = 0.400$ and $y = 0.200$, which, as is seen, was excellent. Attempts to improve the agreement using the two other possible space-groups were fruitless. Hence, in the absence of any evidence to the contrary, the structure of Ni_4W is that based on $C^5_{4h} - I\ 4/m$ with $x = 0.400$ and $y = 0.200$.

The structure is such that each atom has twelve nearest neighbors; W has twelve nearest Ni neighbors, and Ni has three nearest W neighbors and nine nearest Ni neighbors. A Ni atom has one W and three Ni neighbors at a distance of 2.5626Å in the same basal plane, and two W and six Ni neighbors at 2.5377Å in parallel planes above and below the basal plane.

The mechanism by which Ni_4W forms was studied by determining the sequence of changes in the intensities and positions of the lines in X ray diffraction patterns. Samples were aged for various times at temperatures between 750 and 950°C, after an initial solution treatment and quench from 1150°C.

The X ray photograms of the 19.8 at. pct W alloy in the ordered state for shorter aging times also included lines corresponding to the gamma body-centered cubic phase. In all cases, the intensities of the gamma lines were less in the photogram of the ordered state than in the solution treated state, and decreased further upon longer aging. Thus, the gamma phase, as well as the alpha phase, is involved in the reaction which produces the beta phase.

There are two possible mechanisms by which Ni_4W might form, each having a characteristic sequence of diffraction patterns. In an ordering reaction, "the crystal structure of the alloy changes gradually as time proceeds; the lines of the initial pattern change intensity, become diffuse, split into other lines, and, finally, the new lines move into constant positions and become sharp."[4] A phase change on the other hand is indicated by a sequence in which "the lines on the initial pattern remain almost unaltered in position and sharpness, but decrease in intensity during the reaction, while new lines appear and increase in intensity without much change in sharpness or position."

Table 1 . . . 19.8 Atom Percent W Alloy: Solution Treated 17 Hours at 1150°C—Oil Quenched. Then Aged 65 Hours at 950°C—Oil Quenched. Copper K_α Radiation.

hkl	θ	Observed Intensity	Ratio of Intensities $x = 0.400$, $y = 0.200$, $z = 0$		
				Observed	Calculated
110	11.081	8			
101	14.897	10	101/110	1.25	1.30
200	15.651	5½	200/101	0.55	0.56
211	21.840	40	211/200	7.27	15.0
220	22.414	5	220/211	0.13	0.04
310	25.221	25	310/220	5.0	10.2
002	25.785	10	*		
301	27.306	6	301/310	0.46	0.14
112	28.287	6	112/301	1.00	0.97
202	30.767	5	202/112	0.83	0.89
321	32.164	8	321/202	1.60	1.91
400	32.586	2	400/321	0.25	0.24
330	34.867	3	330/400	1.50	1.25
222	35.331	4	222/330	1.33	1.44
411	36.622	5	411/222	1.25	1.97
420	37.039	13	420/411	2.60	3.14
312	37.467	25	312/420	1.92	1.91
103	41.651	4	103/312	0.16	0.08
510	43.351	4	510/103	1.00	1.01
402	43.742	4	402/510	1.00	1.01
501 } 431 }	45.038	20	501 / 431 / 402	5.00	23.4
213 } 332 }	45.859	13	213 / 501 / 332 / 431	0.65	0.54
422	47.928	13	422 / 213 / 332	1.00	0.97
521 } 440 }	49.198	8	521 / 440 / 422	0.62	0.22
303	49.891	4	303 / 521 / 440	0.50	0.41
530	51.681	5	530/303	1.25	1.03
600	53.748	2	600/530	0.40	0.55
512α1 } 323α1 }	54.278	9	323 / 512/ 600	6.75	8.02
512α2 } 323α2 }	54.440	4½			
611	57.822	5½	611 /323 / 512	0.41	0.56
620α1	58.284	8	620/611	2.18	3.00
620α2	58.481	4			
413α1	58.758	5	413/620	0.63	0.35
413α2	58.976	2½			
004α1	60.223	5	*		
004α2	60.477	2½			
442α1	61.134	5	442/413	1.00	0.56
442α2	61.399	2½			
114α1 } 541α1 }	62.622	10	114 / 541/ 442	2.00	3.35
114α2 } 541α2 }	62.910	5			
532α1	63.683	8	532 /114 / 541	0.80	0.72
532α2	63.937	4			
204α1	65.274	5	204/532	0.63	0.57
204α2	65.563	2½			
602α1	66.300	5	602/204	1.00	1.00
602α2	66.647	2½			
631α1	68.035	20	631/602	4.00	13.4
631α2	68.421	10			
433α1 } 503α1 }	69.332	30	433 / 503/ 631	1.50	2.04
433α2 } 503α2 }	69.620	15			
224α1	71.188	5	224 / 433	0.64	0.70
550α1 } 224α2 } 710α1 } 550α2 }	71.867	16	550 / 503, 710		
710α2 }	72.329	8			
622α1	72.639	16	622 / 224, 550, 710	0.83	0.93
622α2	72.112	8			
314α1	74.956	20	314/622	1.25	1.34
314α2	75.543	10			
523α2	76.649	10	523/314	0.50	0.21
523α2	77.214	5			

* I_{00l} does not vary with change in x, y.

At 750°C, for aging times up to 17 hr, the alpha and gamma lines retain their position and intensity, indicating that there is no change in structure. Perhaps longer times at this temperature would have produced appreciable X ray diffraction effects. At 775°C and higher temperatures (800, 850, 900 and 925°C) new lines appear in the diffraction patterns. For shorter aging times, the change in structure is indicated by a blurring of the lines, and, on further aging, the lines sharpen and move into position and new weak lines appear. This behavior is evidence of a mechanism similar to an ordering reaction as opposed to an ordinary phase change.

At 950°C, however, the initial lines retain their position and sharpness, but decrease in intensity while new lines appear in the pattern in the manner characteristic of a phase change. The final structure obtained at this
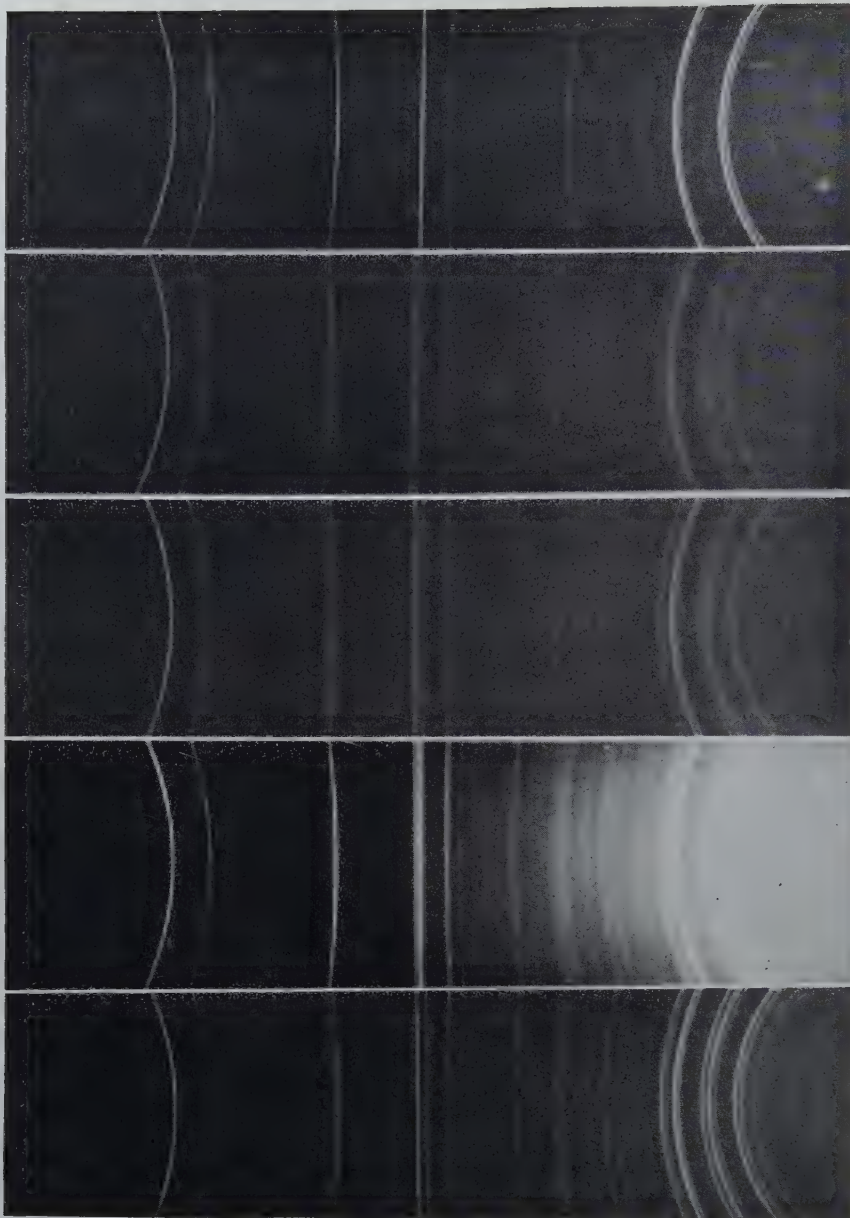
Fig 3

Fig 4

Fig 5

Fig 6

Fig 7

FIG 3—Solution treated for 17 hr at 1150°C—oil quenched. Strong lines of face-centered cubic alpha and weak lines of body-centered cubic gamma.

FIG 4—Solution treated, then aged for 4 hr at 925°C—oil quenched. Beta lines split from alpha lines.

FIG 5—Solution treated, then aged from 17 hr at 925°C—oil quenched. Beta lines shift toward their final positions.

FIG 6—Solution treated, then aged for 17 hr at 950°C—oil quenched. Alpha lines are sharp and strong. Beta lines make their appearance in their final positions.

FIG 7—Solution treated then aged for 65 hr at 950°C—oil quenched. Structure is entirely beta. All lines are in their final positions.

temperature by a phase change is the same as that obtained by a different reaction at the lower temperatures. Thus, the mechanism, but not the product, of the reaction appears to depend upon the temperature. Diffraction patterns illustrating the two sequences of changes in the 19.8 at. pct W alloy are given in Fig 3–7.

The X ray diffraction pattern of a quenched and aged sample of the 17.6 at. pct W alloy (17 hr at 1150°C—oil quenched, and aged 65 hr at 950°C—oil quenched) showed the alpha face-centered cubic phase as well as somewhat diffuse lines of the ordered, body-centered tetragonal structure. Several gamma lines were present in the patterns for shorter aging times, but they decreased in intensity with increased time of aging, indicating that gamma is unstable in the 17.6 at. pct W alloy at 950°C. The beta phase obtained with this sample was not as perfectly crystalline as that shown by the 19.8 at. pct W alloy for the same heat treatment, confirming the fact that the latter is closer to the stoichiometric ratio of the ordered compound.

Samples of the 17.6 at. pct W alloy were aged at various temperatures below 950°C and examined by X ray diffraction. It was found that samples aged below 850°C consist of only the beta phase, while those aged above this temperature are composed of the

FIG 8a–d—17.6 atom percent W alloy. Slightly reduced in reproduction.
a. Solution treated for 17 hr at 1150°C—oil quenched. Alpha matrix with spheroids of gamma. 500 ×.
b. Solution treated then aged for 17 hr at 950°C—oil quenched. Alpha matrix with spheroids of gamma and newly formed regions of beta.
c. Solution treated, then aged for 65 hr at 950°C—oil quenched. Alpha and beta matrix with residual spheroids of gamma.
d. Same sample as Fig 8b, but with oblique light at 1000 ×. Beta phase with striations.

alpha phase as well. These results are evidence that the range of solid solubility of the beta phase is wider than reported by Ellinger and Sykes. It appears that the beta region in the constitution diagram should be extended to the left below 850°C to at least 17.6 at. pct W. No data are available to establish the boundary on the right, that is, at W concentrations above 20 at. pct.

The diffraction pattern of a solution treated (17 hr at 1150°C—oil quenched) sample of the 14.1 at. pct W alloy (34.06 pct by weight), showed lines of only the alpha phase with $a_o = 3.584 \pm 0.001$Å. This result is in agreement with the boundary drawn by Ellinger and Sykes between the alpha and alpha plus gamma fields.

Aging this alloy for 17 hr at 850°C and at 900°C produced no change in the diffraction pattern, although Ellinger and Sykes found a marked increase in hardness for these heat treatments.

METALLOGRAPHY

The microstructure of the alloys in both the quenched and aged conditions were examined. The 19.8 and 17.6 at. pct W alloys in the quenched state showed an alpha solid solution matrix with spheroids of gamma. The alloy with lower tungsten content had less gamma phase. For the aged condition, the microstructures of these two alloys display a decrease in the amount of gamma and the formation of new areas

in the matrix. There is no difference in the type of microstructure obtained with samples aged at 850 and 950°C. These new areas are no doubt the regions of ordered Ni_4W, since they form where gamma is present. Micrographs of the various structures are shown in Fig 8 and 9.

Ellinger and Sykes report that the microstructure of the 14.1 at. pct W alloy in the quenched condition shows a homogeneous solid solution of alpha. After long aging, there is a thickening of grain boundaries and a general darkening of the alpha grains. These authors conclude from this observation that the alloy has decomposed into two phases. This need not be the case, since the same changes in appearance can occur on ordering.
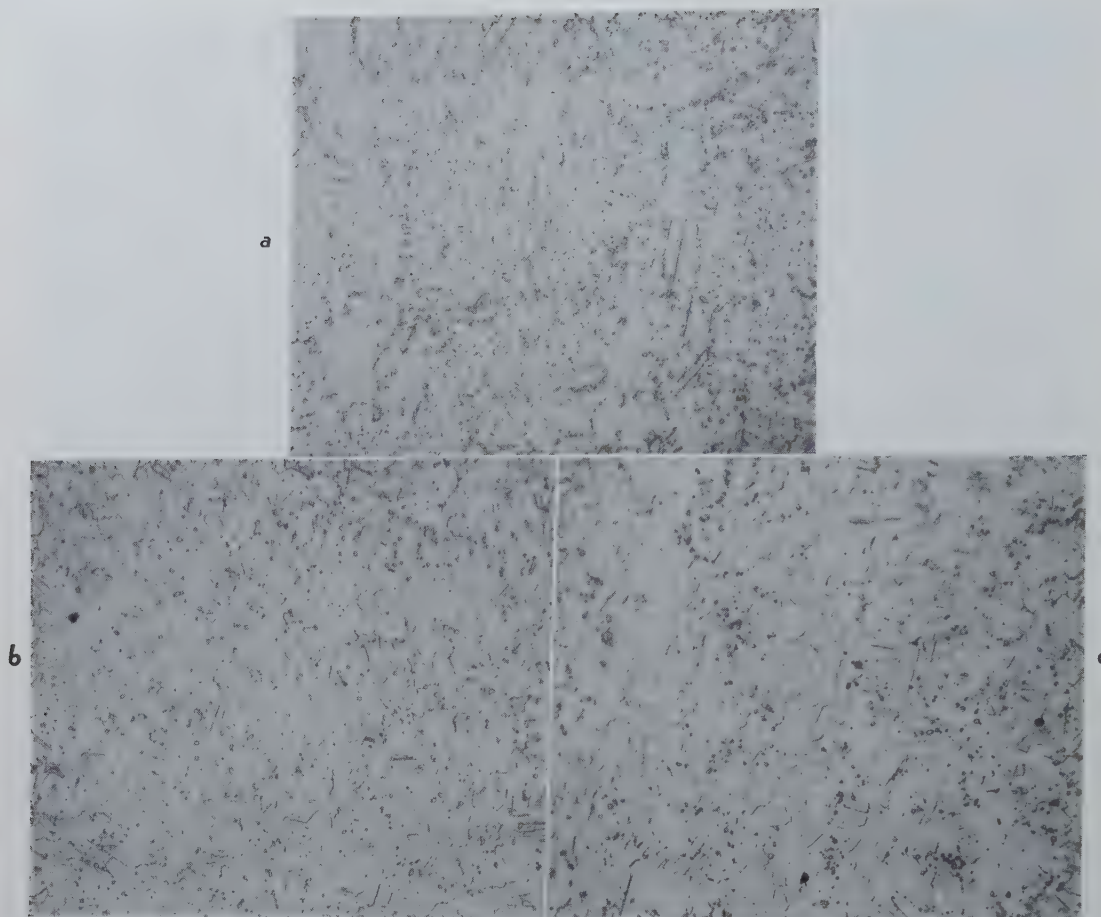
FIG 9a–c—19.8 atom percent W alloy. Slightly reduced in reproduction.
a. Same heat treatment and phases as Fig 8*a.*
b. Same heat treatment and phases as Fig 8*b.*
c. Same heat treatment and phases as Fig 8*c.*

ELECTRICAL RESISTIVITY

Electrical resistivity measurements were made on the 19.8 and 17.6 at. pct alloys in the solution treated and aged conditions. The results obtained are tabulated below:

Table 2 . . . Results of Electrical Resistivity Measurements
Electrical resistivity at room temperature in microhms per cm

Atom percent W	Solution Treated*	Aged†
19.8	110.2	54.4
17.6	125.4	81.2

* 17 hr at 1150°C—oil quenched
† 17 hr at 1150°C—oil quenched
65 hr at 950°C—oil quenched

The sharp drop in electrical resistivity upon aging indicates the migration of atoms to periodically arranged sites in the structure, that is, increasing order. The fact that the resistivity of the 17.6 at. pct W alloy does not drop to as low a value as does the 19.8 at. pct W alloy upon aging at 950°C is explained either by the fact that the former consists of alpha and beta whereas the latter is entirely beta, or that the 19.8 at. pct W alloy is better ordered, being nearer the stoichiometric ratio Ni_4W.

HARDNESS

The hardness of the 19.8 at. pct alloy as a function of the time and temperature of aging was determined. These results are shown in Fig 10, and it is seen that the hardness of the alloy increases in the usual manner as the time and temperature are increased. There is a definite indication of over-aging at all temperatures, and the time of overaging increases with decreasing temperature. The hardening curves at 850 and 950°C appear to be similar in form, but differ from that obtained at 750°C.

Hardness data obtained by Ellinger and Sykes for an alloy similar to the 17.6 at. pct alloy show much the same behavior except that the maximum hardnesses attained are less than those developed in the 19.8 at. pct W alloy.

It is apparent that Ni_4W may be classified as an intermetallic compound since it has a narrow range of homogeneity, a simple stoichiometric formula, and an ordered structure.[6] Beta, as formed in these experiments, is characterized by extreme brittleness, high hardness, and relatively high electrical resistivity.

Summary and Conclusions

At approximately 20 at. pct tungsten in the Ni-W system there exists an ordered beta phase which is an intermetallic compound Ni_4W. Its structure is body-centered tetragonal with $a'_0 = 5.730 \pm 0.001$Å, $c'_0 = 3.553$
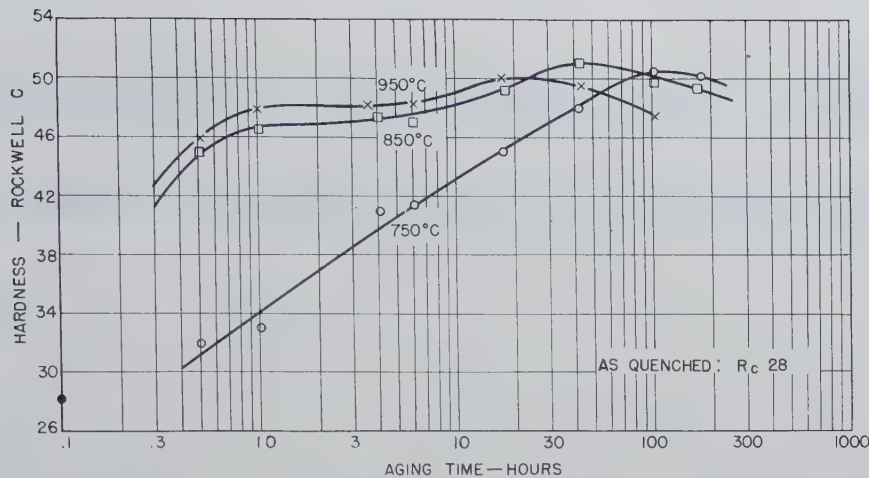
FIG 10—Hardness of 19.8 atom percent W alloy as a function of time and temperature of aging after quenching from 1150°C.

± 0.001Å and $c/a = 0.620$. The unit cell contains two W atoms at 000 and ½ ½ ½ and eight Ni atoms at 0.100 0.300 0.500; 0.200 0.600 0; 0.300 0.900 0.500; 0.400 0.200 0; 0.600 0.800 0; 0.700 0.100 0.500; 0.800 0.800 0; 0.900 0.700 0.500 (space group C^5_{4h} — $I\,4/m$.)

Beta forms upon prolonged heating below 970 ± 10°C from an alpha face-centered cubic phase and a gamma body-centered cubic phase. The structure of Ni_4W is based primarily on the alpha face-centered cubic lattice which undergoes a slight tetragonal distortion. The true unit cell, however, has a volume which is 2.5 times the volume of the small tetragonal cell.

The mechanism of formation of Ni_4W appears to be temperature dependent. On the basis of the sequence of changes in the diffraction patterns, it is concluded that up to quite high temperatures the reaction proceeds by a mechanism similar to ordering but at still higher temperatures occurs by a phase change.

Evidence is presented which shows that the range of solid solubility of the beta phase is wider than reported previously.

The hardness, electrical resistivity, and microstructures of the alloys are discussed.

Acknowledgment

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Sulphur Equilibria between Iron Blast Furnace Slags and Metal

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ONE of the important functions of the iron blast furnace is the desulphurization of pig iron before it enters the steelmaking furnaces. However, the increasing concentrations of sulphur in the metallurgical coke, source of approximately 90 pct of the sulphur present in the blast furnace charge, and demands for higher rates of production within recent years have increased the need for greater desulphurization within the iron blast furnace. Furnace operators are beginning to look for desulphurizing agents other than blast furnace slag to accomplish the desired degree of desulphurization. A considerable amount of work has been done on desulphurization outside the furnace with soda ash, calcium carbide and various synthetic slags. Whether the desulphurization of pig iron is accomplished wholly inside the furnace or partly inside and the remainder outside, will be determined by the economics involved. Regardless of which is the case, it is believed that it is necessary to have a better understanding of the physical chemistry of desulphurization by blast furnace slags. To this end, it is the object of the present investigation to attempt what is believed to be the first equilibrium study of the distribution of sulphur between liquid pig iron and a wide range of blast furnace slag compositions.

Review of Literature

There is a considerable amount of information in the literature concerning the desulphurizing power of iron blast furnace slags, the solubility of various sulphides in the slags, and the effect on desulphurization of temperature, of elements dissolved in the liquid iron, and of viscosity. However, there is nothing to indicate that the equilibrium distribution of sulphur between liquid iron saturated with carbon and iron blast furnace slags has been studied

experimentally.

Wentrup[1] has made probably the most detailed study of the desulphurization of pig iron to date. He considered that there are three distinct aspects involved, namely: 1. Desulphurization within the blast furnace (by lime and manganese). 2. Subsequent desulphurization by manganese. 3. The effect of subsidiary reactions on the desulphurization by manganese.

The experimental work carried out by Wentrup was devoted mainly to obtaining a better understanding of how desulphurization by manganese was accomplished in the mixer and the ladle. Particular attention was given to the part played by carbon, silicon, and phosphorus associated with manganese in the iron, and the effect of temperature on desulphurization. The experimental results indicated that desulphurization by manganese is purely a process of crystallization of manganese sulphide. The addition of silicon to iron melts containing 3.5 pct carbon and less than 0.5 pct manganese had no noticeable effect on desulphurization, but with 1–2 pct manganese the silicon additions improved the desulphurization. Additions of phosphorus also resulted in improved desulphurization by manganese, but the effect was not as marked as in the case of silicon. It was also found that desulphurization by manganese was further improved by lowering the temperature.

In order to explain desulphurization inside the blast furnace, Wentrup considered the system iron, sulphur, calcium, oxygen, manganese, (silicon). The distribution of sulphur between the metal and slag was represented by the following equation:

$$\frac{(\Sigma S)}{[S]} = \frac{(S)Fe + (S)Ca + (S)Mn}{[S]} \quad [1]$$

The parentheses and the brackets represent the equilibrium concentrations in weight per cent of the slag and metal constituents, respectively.

Since

$$FeS \rightleftarrows (FeS)$$

$$L_{FeS} = \frac{(FeS)}{[FeS]} = \frac{(S)Fe}{[S]} \quad [2]$$

$$(CaO) + \underline{S} \rightleftarrows (FeO) + (S)Ca$$

$$K_1 = \frac{(FeO)(S)Ca}{(CaO)[S]}; \quad \frac{(S)Ca}{[S]} = K_1 \frac{(CaO)}{(FeO)} \quad [3]$$

$$\underline{Mn} + \underline{S} \rightleftarrows (S)Mn$$

$$K_2 = \frac{(S)Mn}{[Mn][S]}; \quad \frac{(S)Mn}{[S]} = K_2[Mn] \quad [4]$$

Substitution of Eq 2, 3, and 4 into Eq 1 resulted in

$$\frac{(\Sigma S)}{[S]} = L_{FeS} + K_1 \frac{(CaO)}{(FeO)} + K_2[Mn] \quad [5]$$

Eq 5 was used to calculate $\frac{(S)}{[S]}$ and [S] at 1480°C for slags containing 30–50 pct lime, 0.1–2.5 pct iron oxide, 0–26 pct silica, 2 pct sulphur and iron analyzing 1.5 pct manganese. The value for L_{FeS} at 1480°C was found to be equal to 4.5, based on the experimental work of Bardenheuer and Geller.[2] The results of the calculations are shown in Table 1. Although the slags are hypothetical and do not represent the range of compositions found in ordinary blast furnace practice, the calculations indicate that lime is effective in controlling desulphurization only if the iron oxide and silica contents of the slag are kept low. Schenck[3] did not claim K_1 to be a true equilibrium constant, but an empirical value which varied with the silica content of the slag.

Table 1 . . . Calculations for the Fe-S-Ca-Mn-O(-Si) System
(By Wentrup)

	Pct CaO	Pct FeO	Pct SiO$_2$	Pct [Mn]	(S)Fe / [S]	(S)Ca / [S]	(S)Mn / [S]	(ΣS) / [S]	Pct (S)	Pct [S]
1	30	0.1		1.5	4.5	857	15	876.5	2	0.0023
2	30	1.0		1.5	4.5	85.7	15	145.2	2	0.0138
3	30	2.5		1.5	4.5	34.3	15	53.8	2	0.0380
4	50	0.1		1.5	4.5	1430	15	1449.5	2	0.0014
5	50	1.0		1.5	4.5	143	15	162.5	2	0.0135
6	50	2.5		1.5	4.5	57.3	15	66.8	2	0.030
7	30	0.1	26	1.5	4.5	40	15	59.5	2	0.034
8	30	1.0	26	1.5	4.5	4	15	23.5	2	0.085
9	30	2.5	26	1.5	4.5	1.6	15	21.1	2	0.095
10	40	0.1	26	1.5	4.5	53.4	15	72.9	2	0.027
11	40	1.0	26	1.5	4.5	5.34	15	24.84	2	0.081
12	40	2.5	26	1.5	4.5	2.13	15	21.63	2	0.093
13	50	0.1	26	1.5	4.5	66.8	15	86.3	2	0.023
14	50	1.0	26	1.5	4.5	6.7	15	26.2	2	0.075
15	50	2.5	26	1.5	4.5	2.6	15	22.1	2	0.090

Holbrook[5,6] and Joseph studied the desulphurizing power of blast furnace slags. From their experiments carried out under standardized laboratory conditions, desulphurizing power was defined as being equal to the ratio:

$$\frac{\%\ \text{sulphur in slag}}{\%\ \text{sulphur in metal}} = \frac{(\%\ S)}{[\%\ S]}$$

No mechanical method of mixing the slag and metal was employed in this work, as the investigation was not concerned with attainment of equilibrium but with the determination of the relative desulphurizing powers of slags under controlled laboratory conditions. It was found that in magnesia-free slags the desulphurizing power increases rapidly as lime replaces silica; less rapidly as lime replaces alumina and slowly as alumina replaces silica. The desulphurizing power decreases slightly with the addition of magnesia to the acidic slags and increases markedly when magnesia is added to the very basic slags. Magnesia decreases the viscosity of the slags, and thereby allows the very basic slags to exhibit their inherently strong desulphurizing qualities. Holbrook and Joseph also suggested that the evolution of carbon monoxide accompanying desulphurization retards the descent of falling metal drops and carries calcium sulphide and globules of metal away from the bath interface and into the slag, contributing to the effectiveness of the reaction.

McCaffrey and Oesterle[7] have carried out comprehensive experiments on the solubility of calcium sulphide and manganese sulphide in slags of the ternary system, silica, lime, and alumina. Their results indicate that the solubility limit of sulphur as calcium sulphide and manganese sulphide is considerably higher than the sulphur content of ordinary blast furnace slags, and that the actual chemical composition of the slag is of less importance than the temperature of the slag in affecting sulphur solubility.

Imhoff[9] has claimed that sulphur occurs in three forms in blast furnace slags: (1) combined as calcium sulphide; (2) free sulphur held in solution in the slag and (3) sublimed sulphur, the result of excess sulphur in the burden.

Martin, Glockler, and Wood[10] examined in the laboratory the forms in which ferrous sulphide, manganese sulphide, and calcium sulphide occur in a blast furnace slag. The glasses obtained by quenching a molten slag to which the sulphides were added separately, were shown to contain a colloidal phase. The data indicated that the sulphides are present also in solution in the slag. The authors believed that the colloidal particles were sulphides and that the colloidal condition was present in the molten slag, as heat treatment below the softening point did not affect the intensity of the colloid. In order to explain the stability of the colloidal phase in molten slags Martin and Glockler proposed an ionic constitution for blast furnace slags.

The work by Martin and Derge[16] on the electrical conductivity of molten blast furnace slags has provided further evidence of high degrees of ionization. Herasymenko[17] has proposed that molten slags are completely ionized.

In contrast to the ionization concept has been the older molecular theory of blast furnace constitution. The researches of McCaffrey,[11] Field and Royster,[8] Hay[12] and others on the viscosity of mixtures of lime, silica, alumina, and magnesia at temperatures well above their melting points, show that the slags behave in a manner similar to simple solutions, the changes in viscosity with change of composition being relatively small. However, McCaffrey,[13] and Colclough[14] have stated that in the temperature range 50–100°C above the melting range blast furnace slags are composed of minerals of definite composition and properties.

Abell[15] also was convinced that molten blast furnace slags are composed of molecular compounds. However, he proposed that the slags are composed of spinels and silicates and maintained that the silicates act as comparatively inert solvents for the spinels which alone are capable of reacting with the sulphur in the iron.

Experimental Method

FURNACE

In order to study the equilibrium distribution of sulphur between iron blast furnace slags and liquid iron saturated with carbon, a small induction furnace was built, which held a graphite crucible containing 200 g of metal and 400 g of slag. The amount of metal was determined by the maximum number of samples that would be required in any run. The comparatively large amount of slag was believed to be sufficient to maintain the slag at constant composition over the narrow temperature range employed.

Carbon monoxide gas is evolved in the desulphurization reaction. If an equilibrium state was to be maintained, the partial pressure of this gas had to be held constant. Thus carbon monoxide was used as the furnace atmosphere. Since the crucible was to be made of graphite, little or no stirring of the metal could be expected from electro-magnetic forces. Thus it was proposed to attain the equilibrium state by stirring the slag and metal with a graphite stirring rod.

The induction furnace is shown in Fig 1. The graphite crucible, M, is 7 in. long and 2¼ in. id with a wall thickness of ⅜ in., and it contains a well, 1 in. in diam and ¼ in. in depth, which provides an additional depth of metal for sampling. The crucible is insulated on all sides by a porous carbon tube, K, and by porous carbon blocks, L and P. Lampblack is packed between the porous carbon tube and the silica tube, I, to further insulate the furnace. The silica tube is placed in an annular slot, fitted with a silicone gasket, on the soapstone base.

A water-cooled brass plate, C, closes off the top end of the silica tube. The brass plate is fitted with a rubber gasket. Three holes were drilled in the plate to serve as inlets for taking samples and temperature measurements, for inserting the graphite stirring rod and the graphite tube containing the carbon monoxide gas.

The graphite stirring thimble is threaded into the stirring rod, which is attached to the chuck of a $\frac{1}{50}$ hp variable speed electric motor. Carbon monoxide gas contained in a high pressure cylinder is passed first through a precision bore rotameter tube, before entering the furnace by means of a graphite tube. This graphite tube is $\frac{1}{8}$ in. id and 21 in. long with a $\frac{3}{16}$ in. wall thickness. The tube rests on the furnace bottom, thus causing the gas to flow through both the metal and slag layers. Both the stirring rod and graphite tube are fitted with brass bushings which rest on the brass plate. The furnace is thus closed to the atmosphere at all points except for the sampling-temperature measuring hole. This insures that all the carbon monoxide is withdrawn from the furnace and burned at one point.

METAL AND SLAG CHARGES

High-carbon wash metal was used as the source of iron. When it was desired to approach equilibrium from the side of high sulphur in the metal, ferrous sulphide was added to the metal. In order to approach equilibrium from the slag side a low sulphur melting stock was prepared, which consisted of electrolytic iron melted in contact with a graphite rod, and calcium sulphide was used as the source of sulphur in the slag. In those runs in which the silica content of the slag was high, silicon metal was added to the metal charges to decrease the amount of transfer of silicon from slag to metal. In order to homogenize the slags as much as possible before using them in the experimental furnace, a series of eight master slags were melted in graphite crucibles. These master slags were made up from mixtures of chemically pure lime, purified silica sand, alumina, and magnesia. They were crushed, sampled, and analyzed. Slag charges for the experimental runs were readily prepared from the master slags, with small additions of the pure constituents as required to produce slags of the desired analyses.

TEMPERATURE MEASUREMENT

In the first run, the temperature was measured with both an optical pyrometer and a platinum-platinum, 10 pct rhodium thermocouple. The optical pyrometer was sighted down a $\frac{1}{2}$ in. id graphite tube, which had its lower end closed off. The readings taken with the thermocouple inside
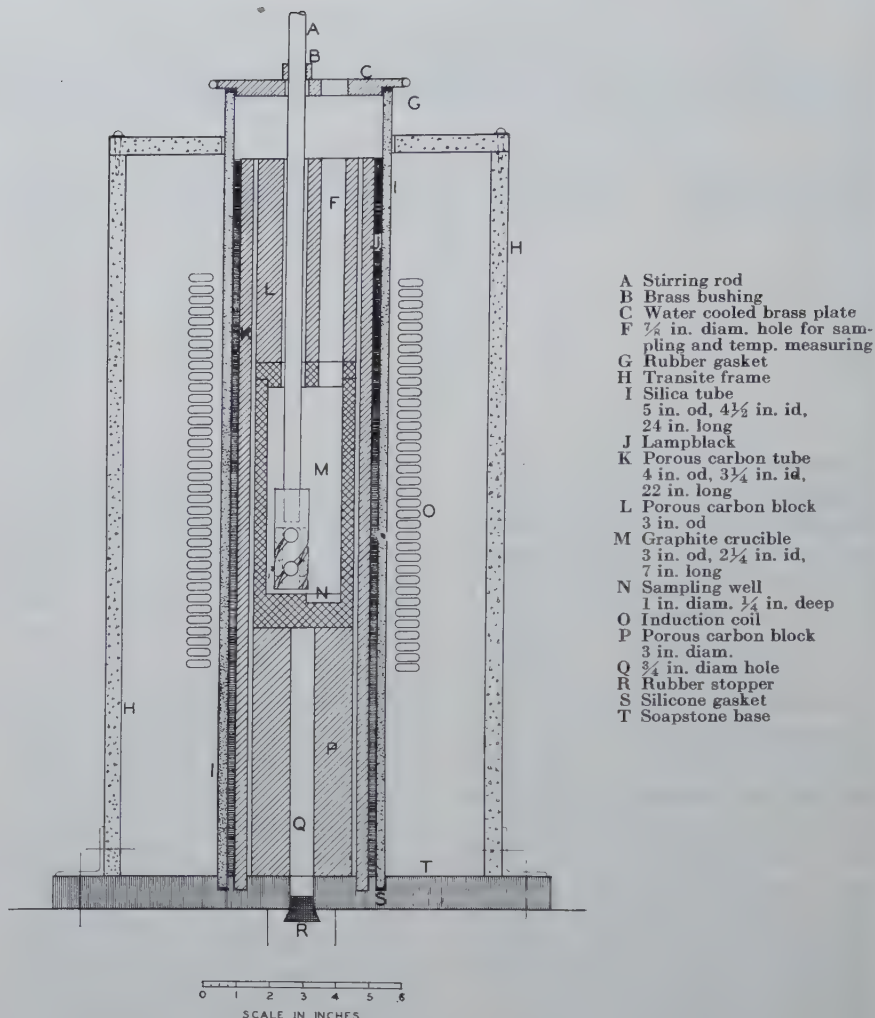
A   Stirring rod
B   Brass bushing
C   Water cooled brass plate
F $\frac{1}{4}$ in. diam. hole for sampling and temp. measuring
G   Rubber gasket
H   Transite frame
I   Silica tube
    5 in. od, $4\frac{1}{2}$ in. id, 24 in. long
J   Lampblack
K   Porous carbon tube
    4 in. od, $3\frac{1}{4}$ in. id, 22 in. long
L   Porous carbon block
    3 in. od
M   Graphite crucible
    3 in. od, $2\frac{1}{4}$ in. id, 7 in. long
N   Sampling well
    1 in. diam. $\frac{1}{4}$ in. deep
O   Induction coil
P   Porous carbon block
    3 in. diam.
Q $\frac{3}{4}$ in. diam hole
R   Rubber stopper
S   Silicone gasket
T   Soapstone base

SCALE IN INCHES

FIG 1—Details of furnace.

the graphite tube checked within $\pm 2°C$ at 1500°C with those taken simultaneously with the optical pyrometer. Thus, since the true black body temperature was obtained with the optical pyrometer, and as the temperature was so readily measured this way, the optical pyrometer was used exclusively in all subsequent runs. The platinum-platinum, rhodium thermocouple served to check the optical pyrometer periodically. The main source of error with respect to temperature was not in the measurement but in the difficulty of maintaining the temperature constant by means of the manually operated power supply. It was found that the temperature could be held only within $\pm 10°C$ of the desired value for the duration of each run.

FURNACE OPERATION

From the experience gained in the early runs the following procedure was

found to be satisfactory in establishing equilibrium:

Two hundred grams of wash metal were charged into the crucible. With the stirring rod resting on the metal charge, the graphite cover, the porous carbon insulating block and the brass plate were placed in position. Four hundred grams of slag of the desired composition and having 1.5 pct sulphur as calcium sulphide were then introduced into the crucible by means of a funneled pyrex tube. The water and power were turned on and the furnace was purged out with nitrogen. After the charge was melted, the stirring mechanism was clamped so that the bottom of the stirring thimble was $\frac{1}{8}$ of an inch from the bottom of the crucible. The stirrer was started and operated at 500 rpm. The nitrogen gas was turned off and carbon monoxide was introduced, at approximately 900 ml per min., down into the melt by means of the graphite tube which rested on the furnace bottom. A pilot

flame was maintained at the mouth of the sampling hole to insure that the carbon monoxide burned as it was discharged from the furnace. In case any carbon monoxide escaped unburned, an exhaust hood was placed close to the furnace.

The temperature was adjusted to the desired value and maintained at that value for the duration of each run by adjusting the power input. Experience with various slags indicated that the sulphur equilibrium was attained in 4 to 6 hr time, depending on the viscosity, temperature, and composition of the slag. As a result, the duration of the runs was established at 7 hr. Metal samples were taken at end of 5, 6, and 7 hr. The metal sampler consisted of thin-walled silica tube, $3/16$ in. id, attached to a rubber aspirator bulb. No real difficulty was experienced in obtaining sound 10 to 15 g samples provided the slag was not too viscous. The slag was sampled at the end of the run by dipping a $5/8$ in. diam brass rod into the slag layer. The last metal sample was analyzed for sulphur, carbon, and silicon, while the first and second samples were analyzed for sulphur only. A complete analysis was made on the slag sample. Both the metal and slag samples were analyzed for sulphur by the combustion method. This method consists of igniting the sample at 1300 to 1400°C in a stream of oxygen. The gas given off from the sample is bubbled into a 3 pct solution of hydrochloric acid and titrated as it is evolved with potassium iodate solution. The combustion method takes less sample, 1 g of metal or 0.2 g of slag, than either the volumetric or gravimetric method. It is more accurate than the volumetric and is much less tedious to perform than the gravimetric. The sulphur determinations on the metal samples by this method are accurate within ±0.001 pct sulphur. An analysis is completed in less than 10 min. time.

SLAG VISCOSITY AND SLAG-TO-METAL TRANSFER OF SILICON

At temperatures above 1500°C, a few preliminary runs demonstrated that in a graphite crucible liquid iron could absorb as much as 10 pct silicon from a slag containing more than 40 pct silica. Since the effect of such high percentages of silicon on the equilibrium concentration of sulphur has not been determined experimentally, it was planned to maintain the silicon content in the metal at less than 2 pct. In order to do this, the maximum allowable concentration of silica in the slag was estimated to be 35 pct, with a maximum temperature of 1500°C. On the other hand, since the viscosity of slags increases with decrease in temperature, for any given slag there is a temperature below which it is not feasible to carry out any equilibrium studies. The work by McCaffrey on viscosity measurements of blast furnace slags proved invaluable in determining this lower temperature limit. From McCaffrey's data and from the experience gained in the first seven runs it was found that 1400°C was about the lowest temperature at which an appreciable range of slag compositions could be investigated.

On the basis of the above considerations, a series of runs was made at 1425°C in order to determine the relationship between slag composition and desulphurization. Runs were also made at 1500°C to study the effect of temperature on desulphurization.

In runs H-31 and H-37 the silicon concentrations in the metal were 3.23 and 4.80 pct, respectively. These higher silicon concentrations did not appear to affect the sulphur equilibrium. In addition, calculations by Chipman on the activities of liquid iron in the iron-silicon-carbon system indicated that the activity of iron is only slightly affected by additions of up to 10 pct silicon to liquid iron saturated with carbon. Also, the work of Wentrup on the desulphurization of pig iron by manganese showed that silicon did not affect desulphurization provided that the manganese concentration was less than 0.5 pct. On the basis of these facts it was assumed that silicon does not greatly affect the sulphur equilibrium concentration in liquid iron saturated with carbon.

Although the present investigation was concerned primarily with the equilibrium distribution of sulphur between slag and metal it was interesting to determine whether an equilibrium was established with respect to silicon. It was found that the silicon equilibrium was much more slowly attained than was the sulphur equilibrium between slag and metal. This fact was demonstrated when runs H-19, H-24, H-25, and H-36 were remelted and more sulphur was added in order to study the effect of an increase in the sulphur content of the slags on the sulphur

equilibrium. In these remelted runs, it was observed that the silicon concentrations in the metal were higher than they had been in the original runs, showing that equilibrium with respect to silicon had not been originally attained. It was interesting to note that in the original runs, even though the silicon equilibrium was not attained, lowering the temperature from 1550 to 1425°C caused the silicon slag-to-metal transfer to reverse, and hence resulted in a decrease in the silicon content of the metal. This indicated that the temperature coefficient for the silicon equilibrium is very high.

In run H-33, the silicon equilibrium was approached from both sides by first holding the temperature at 1500°C for 6 hr, followed by 1 hr at 1600°C and then $3\frac{1}{2}$ hr at 1500°C. The equilibrium state was found to lie between 1.71 and 2.29 pct silicon in the metal. This run was remelted and maintained at 1500°C for another 7 hr. At the end of this period the metal analyzed 2.08 pct silicon. On the basis of these results, the remelted runs H-34, and H-44 to H-48, are considered to have approximated equilibrium with respect to silicon.

ATTAINMENT OF THE SULPHUR EQUILIBRIUM

Ferrous sulphide was the only source of sulphur available in the early runs. Consequently at the beginning of each run the slag-metal system was far removed from equilibrium and the initial sulphur transfer to the slag was extremely rapid as was evidenced by the strong bubbling of the slag and the evolution of carbon monoxide gas. However, the bubbling action soon stopped and the rate of sulphur transfer proceeded extremely slowly thereafter, so slowly that the sulphur content of the metal had not reached a constant value after 5 hr with a stirrer speed of 100 rpm. In order to improve the possibility of attaining equilibrium within a reasonable length of time, the speed of the stirring rod was increased to 500 rpm in run H-8. However, the increased stirring speed did not greatly improve the rate of attaining equilibrium.

Since the equilibrium concentrations of sulphur in the metal for the various slags studied appeared to be quite low it was believed that the equilibrium state might be more readily approached from the side of high sulphur in the slag. In runs H-9 and H-14, sulphur, as calcium sulphide, was added to the slag charge. The sulphur reached a con-

stant value after 4 and 2 hr in runs H-9 and H-14, respectively. This difference in the time required to reach equilibrium was occasioned by (1) temperature, run H-9 being at 1425°C and H-14 at 1500°C, and (2) slag composition, the slag used in run H-14 being much more basic than in run H-9.

In an effort to further decrease the time to equilibrium carbon monoxide was bubbled into the metal and slag at approximately 600 ml per min. in run H-17. Thus with calcium sulphide as the source of sulphur, with the stirrer operating at 500 rpm and with carbon monoxide bubbling through the bath, it appeared that 4 or 5 hr was sufficient time for any slag to come to equilibrium with the metal. Consequently, in run H-19 the temperature was held constant at 1500°C for 5 hr and then it was decreased to 1425°C where it was maintained for 4 hr. This procedure was adhered to from run H-19 to H-30, except where viscosity and silicon-transfer considerations did not permit the slag to be studied at both 1500 and 1425°C.

The results of the analyses on these runs showed that the sulphur content of the metal increased when the temperature was lowered from 1500 to 1425°C. However, the analyses also revealed that equilibrium had not been attained in all these runs. Thus, beginning with run H-31, the furnace was held at one temperature for 7 hr and the rate of flow of carbon monoxide was increased from 600 to 900 ml per min. This practice insured the attainment of equilibrium, and was followed in all the succeeding runs.

It must be pointed out that in every run in which calcium sulphide was used as the source of sulphur, the successive metal samples did not increase in sulphur, but rather decreased, until the equilibrium concentration was obtained. A typical example of this fact is shown in Fig 2. This was true even when electrolytic iron which contained less than the equilibrium concentration of sulphur was used. The high sulphur content of the first metal samples was probably due to the calcium sulphate present in the calcium sulphide charged into the crucible.

The plot of per cent sulphur in the metal against the time sampled, shown in Fig 3, demonstrates that the sulphur equilibrium can be approached from the slag side. Calcium sulphide was the source of sulphur in this run. The temperature was maintained at 1425°C for 6 hr so as to allow the transfer of
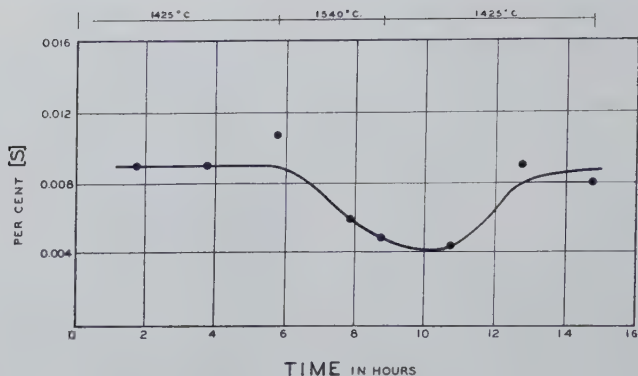

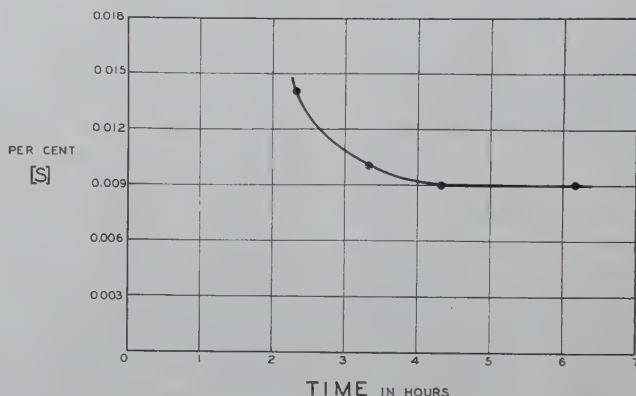FIG 2—Typical determination of equilibrium at 1500°C.

FIG 3—Equilibrium approached from slag and metal sides.

sulphur from the metal to the slag until equilibrium was attained. The temperature then was increased to 1550°C and held constant for 3 hr, in order to decrease further the sulphur concentration of the metal. Nitrogen gas was bubbled through the melt during this period to aid in the metal-to-slag transfer of sulphur. At the end of the 3 hr period, the temperature was lowered again to 1425°C and maintained for 6 more hours. The sulphur content returned to its former value corresponding to equilibrium at this temperature.

SULPHUR CONTENT
OF THE SLAGS

The slags in most of the first 38 runs analyzed 1.5 pct sulphur. This percentage of sulphur in the slag resulted in very low sulphur concentrations in the metal, especially with the more basic slags. Thus it was believed desirable to increase the sulphur concentration in the slags in order to increase the sulphur content of the

metal, and thereby improve the accuracy of the sulphur determinations on the metal samples. Nine of the original runs were remelted and iron sulphide was added in quantities to give approximately 2.5 pct sulphur in the slags. Examination of the analytical results for these runs indicated that the sulphur concentration in the metal did not increase proportionally to the increase of sulphur in the slag. As a result, three runs were made with slags containing approximately 5 pct sulphur. Although the percentages of sulphur found in the metal samples for these runs were higher than would occur with similar slags containing 1.5 pct sulphur, they were much lower than would be the case if the sulphur in the metal was proportional to the sulphur in the slag.

IRON CONTENT OF THE SLAGS

Iron is probably present in blast furnace slags as iron oxide, iron sulphide and as metallic iron. Although it is known that the concentration of

Table 2 . . . Iron Content of Slags at 1500°C

Run No.	Pct FeO	Run No.	Pct FeO
H-19	0.027	H-44	0.034
H-24	0.033	H-47	0.044
H-31	0.046	H-48	0.030
H-34	0.030	H-49	0.026
H-37	0.026	H-51	0.039
H-39	0.031	H-54	0.100
H-40	0.029	H-55	0.065
H-41	0.020	H-56	0.050

Table 3 . . . Chemical Analyses of Slag-metal Samples

Run No.	Temp. °C	Iron Analysis, Pct			Slag Analysis, Pct					
		C	Si	S	CaO	SiO₂	MgO	Al₂O	FeO*	S
H-9	1425	4.67	0.53	0.013	42.70	35.14	7.75	13.72	0.20	2.07
H-14	1500	4.83	0.55	0.005	48.30	29.69	10.58	10.14	0.46	1.58
H-15	1425	4.18	2.41	0.058	35.20	42.88	5.70	14.68	0.20	1.48
H-16	1425	4.27	1.37	0.038	39.95	38.65	5.97	14.86	0.20	1.51
H-17	1500	4.76	0.65	0.006	49.52	30.06	5.71	14.92	0.35	1.56
H-18	1425	4.25	1.62	0.028	35.79	33.67	5.36	26.26	0.41	1.54
H-19	1500	4.54	1.40	0.006	50.01	34.20	5.65	10.48	0.23	1.59
	1425	4.41	1.05	0.007						1.58
H-21	1500	4.78	0.91	0.009	35.04	29.70	14.84	19.86	0.25	1.51
	1425	4.62	0.74	0.011						1.49
H-24	1500	4.53	1.41	0.009	48.60	33.42	0.08	16.82	0.28	1.47
H-25	1500	4.86	0.79	0.006	34.90	31.10	18.65	13.54	0.25	1.50
	1425	4.65	0.45	0.007						1.51
H-28	1500	4.48	1.76	0.013	45.58	32.10	1.47	19.98	0.22	1.45
H-31	1500	4.12	3.23	0.017	35.79	30.48	6.68	25.98	0.27	1.53
H-32	1500	4.28	2.53	0.012	40.00	34.24	8.34	17.28	0.19	1.62
	1425	4.29	1.83	0.013	39.79	34.44	8.45	17.14	0.30	1.61
H-33	1500	4.51	2.28	0.0075	40.14	33.63	13.53	12.20	0.30	1.59
	1425	4.56	0.91	0.008						1.56
H-34 (H-24 remelted)	1500	4.42	2.05	0.010	48.60	33.42	0.08	16.82	0.20	2.24
H-35	1500	4.71	1.23	0.007	38.03	35.45	18.19	7.79	0.19	1.48
	1425	4.71	0.69	0.010						1.48
H-36	1500		0.84	0.007	39.81	31.64	16.19	11.40	0.19	1.54
H-37	1500	3.70	4.80	0.011	41.80	37.86	5.33	14.30	0.19	1.57
	1425	3.76	3.79	0.015						1.56
H-38	1500	4.33	2.18	0.011	35.40	28.96	9.80	25.70	0.20	1.56
H-39 (H-8 remelted)	1500	3.95	2.53	0.011	37.27	34.00	15.03	12.40		2.47
H-40 (H-6 remelted)	1500	3.27	6.04	0.011	47.86	40.00	5.41	5.80		2.56
H-41 (H-13 remelted)	1500	3.82	4.14	0.014	37.20	31.54	10.70	18.84	0.23	2.61
H-42	1425	4.24	2.46	0.019	35.79	30.48	6.68	25.98		1.61
H-44 (H-19 remelted)	1500	4.47	1.85	0.006	49.66	33.80	5.94	10.92		2.25
H-45 (H-25 remelted)	1500	4.68	1.24	0.009	34.90	31.10	18.65	13.54		2.35
H-46 (H-33 remelted)	1500	4.44	2.08	0.009	40.14	33.63	13.53	12.20	0.30	2.34
H-47 (H-28 remelted)	1500	4.04	3.37	0.010	46.25	30.84	1.21	21.10		2.18
H-48 (H-36 remelted)	1500	4.76	1.19	0.006	39.46	31.18	16.55	12.00		2.48
H-49	1500	3.52	5.28	0.016	31.00	32.20	9.35	25.92	0.30	1.54
H-51	1500	4.45	1.93	0.007	51.70	36.08	1.45	10.32	0.30	1.61
H-54	1500	3.01	7.25	0.024	35.40	35.50	9.49	16.40		4.66
H-55	1500	3.63	5.04	0.017	38.41	33.36	9.44	15.66		4.59
H-56	1500	3.99	3.80	0.012	46.80	35.56	7.50	7.12		4.83
H-57	1425	4.29	1.69	0.009	42.50	34.86	7.51	12.96		1.35

*FeO after incomplete magnetic separation. Compare Table 2 showing results after repeated magnetic treatment.

iron is low in blast furnace slags, it was believed to be advantageous to determine the quantity of combined iron present in the slags studied in the present investigation. The mixing of the slag and metal by the graphite stirring rod caused iron to be dispersed throughout the slag. As a result, even though the slag was allowed to stand for at least one minute before being sampled, tiny droplets of iron were present in the slag samples. This magnetic iron was separated roughly by means of a magnet. The concentration of iron remaining after this separation was found to be 0.2 to 0.5 pct, reported as iron oxide (Table 3). In order to determine the degree to which the simple magnet had removed the metallic iron, several slag samples were passed over a Franz iso-dynamic separator. These slag samples included slags containing 1.5, 2.5, and 5.0 pct sulphur. The samples were passed over the separator until their iron contents became as nearly constant as could be detected by the colorimetric method used for chemical analysis. The results of these analyses are shown in Table 2 where the iron is reported as iron oxide. These figures do not give a true value for iron oxide as they include any iron sulphide present in the slag, but they provide a good indication of the amounts of chemically combined iron in blast furnace slags at equilibrium with liquid iron saturated with carbon. The iron content did not appear to be related to the sulphur concentration in the slag.

Results

The results of chemical analyses of the slag and metal samples for the equilibrium runs are shown in Table 3. The only significant sources of error from chemical analysis occurred in the analytical results obtained for sulphur in the metal. Eight metal samples that had been analyzed for sulphur were re-labeled and submitted for analysis again. The two sets of results differed in all but one case, by not more than 0.001 pct sulphur. (Table 4.) However, the desulphurization ratio, $\frac{(S)}{[S]}$, weight per cent of sulphur in the slag divided by weight per cent of sulphur in the metal, can be considerably affected by even this small change in the sulphur content of the metal. A comparison of run H-19 with H-44 illustrates this point. Run H-44 was a remelt of run H-19 to which more sulphur as iron sulphide had been added.

	(S)	1st Analysis		2nd Analysis	
		[S]	$\frac{(S)}{[S]}$	[S]	$\frac{(S)}{[S]}$
H M 19d	1.59	0.006	265	0.005	318
H M 44c	2.25	0.006	375	0.007	322

These figures demonstrate the difficulties involved not only in correlating the desulphurization ratio with slag composition, with the more basic slags, at a constant sulphur concentration in the slag, but also in determining whether or not the sulphur in the metal is directly related to the sulphur in the slag.

Table 4 . . . Rechecked Sulphur Determinations on Metal Samples

Run No.	Pct Sulphur	
	1st Analysis	2nd Analysis
H-19	0.006	0.005
H-24	0.009	0.009
H-34	0.010	0.012
H-39	0.011	0.012
H-40	0.011	0.012
H-41	0.014	0.013
H-44	0.006	0.007
H-46	0.009	0.009

EFFECT OF SLAG COMPOSITION ON DESULPHURIZATION

Since the majority of the runs were made at 1500°C with slags containing 1.5 pct sulphur, it was believed that a relationship between desulphurization and slag composition could best be established from the data collected in these runs. Desulphurization of pig iron is known to depend on the basicity of the slag; thus there was the possibility that the desulphurization ratio, $\frac{(S)}{[S]}$, might be simply related to an index of basicity.

All slag analyses were converted to mols per 100 g of slag. In the chemical analysis of the slags all the calcium present was reported as lime. Any calcium present in the form of calcium sulphide was included in the total molar concentration of lime and was, therefore, considered to act as a base.

Plots were made of the desulphurization ratio versus the molar ratios $\frac{CaO}{SiO_2}$, $\frac{CaO}{SiO_2 + Al_2O_3}$, $\frac{CaO + MgO}{SiO_2}$, and $\frac{CaO + MgO}{SiO_2 + Al_2O_3}$, respectively. Of these plots the one of $\frac{(S)}{[S]}$ versus $\frac{CaO + MgO}{Al_2O_3 + SiO_2}$ (Fig 4) gave by far the best correlation in relating the desulphurization ratio to basicity. In this plot it was noted that all but one of the points below the line represent slags containing more than 6 pct magnesia, while all but one of the points above the line represent slags containing less than 6 pct magnesia. This fact indicated that magnesia is not as effective a desulphurizing agent as lime. The substitution of various factors for K in the basicity ratio $\frac{CaO + K \cdot MgO}{SiO_2 + Al_2O_3}$ showed that the factor of $\frac{2}{3}$ resulted in the closest correlation of the points representing slags with high and low magnesia concentrations. (Fig 5)

It can be said that the relating $\frac{(S)}{[S]}$ to a basicity ratio, a good correlation of the data might be obtained by the use of factors for any or all of the four constituents lime, magnesia, silica, and alumina. Thus it was believed that a more quantitative relationship might be developed if the desulphurization ratio could be expressed as some function of excess base, in a manner analogous to that employed by Grant and Chipman[4] in their study of sulphur equilibrium between liquid iron and basic open hearth slags. Since blast furnace slags are considered to consist mainly of bisilicates, it was first assumed that 1 mol of acid neutralized 1 mol of base, that 1 mol of magnesia was equivalent to 1 mol of lime, and that 1 mol of alumina was as effective as 1 mol of silica. Excess base thus became equal to BASES (CaO + MgO) —ACIDS (SiO$_2$ + Al$_2$O$_3$). A graph of the desulphurization ratio versus this expression for excess base (Fig 6) produced a scattering of the points comparable to that obtained when the ratio $\frac{CaO + MgO}{SiO_2 + Al_2O_3}$ was employed as
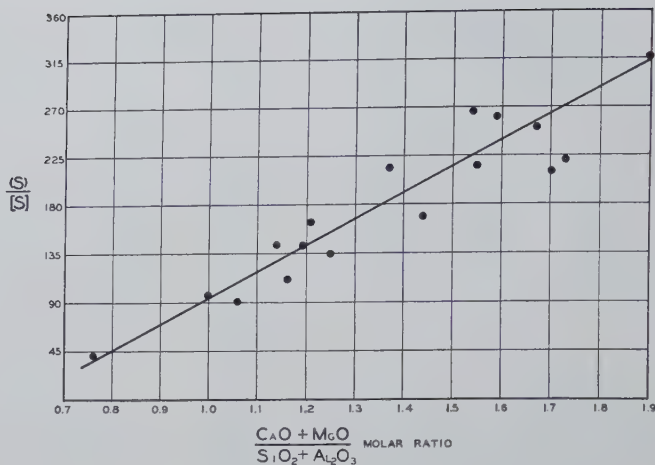
FIG 4—Effect of $\frac{CaO + MgO}{SiO_2 + Al_2O_3}$ on desulphurization at 1500°C.
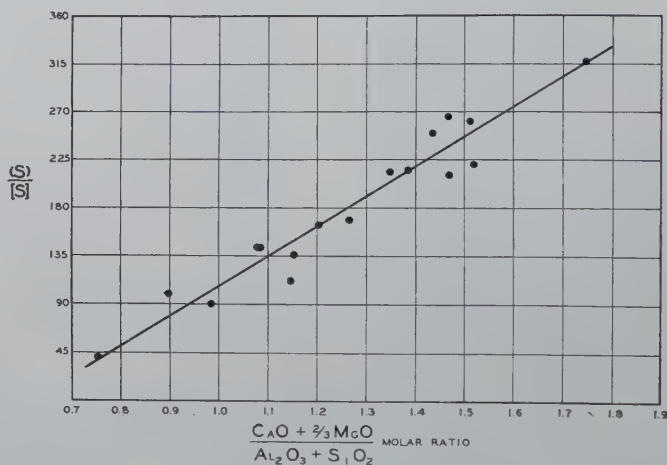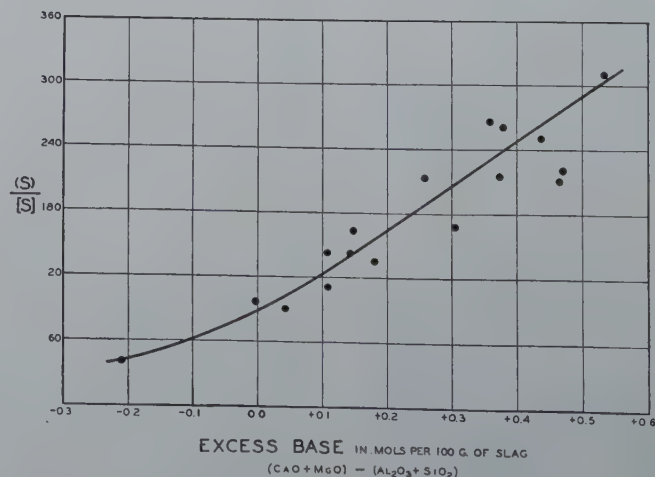

FIG 5—Effect of basicity on desulphurization at 1500°C.

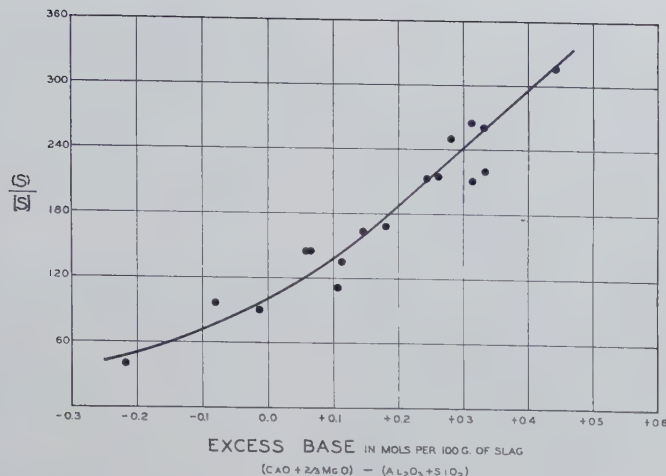FIG 6—Effect of (CaO + MgO) − (SiO$_2$ + Al$_2$O$_3$) on desulphurization at 1500°C.

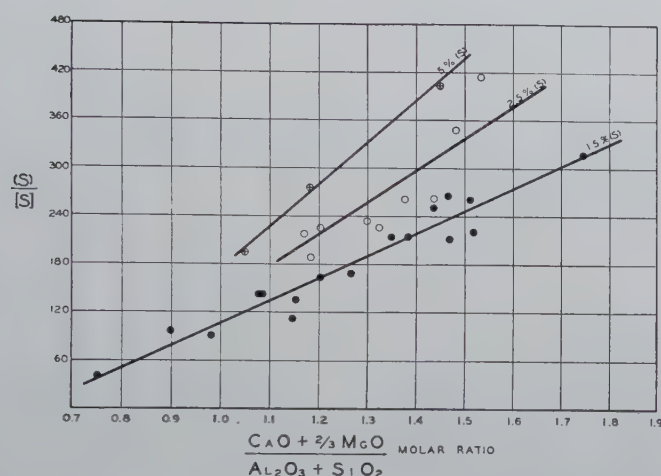FIG 7—Effect of excess base on desulphurization at 1500°C.

FIG 8—Relationship between basicity and desulphurization at 1500°C for 1.5 to 5 pct sulphur slags.
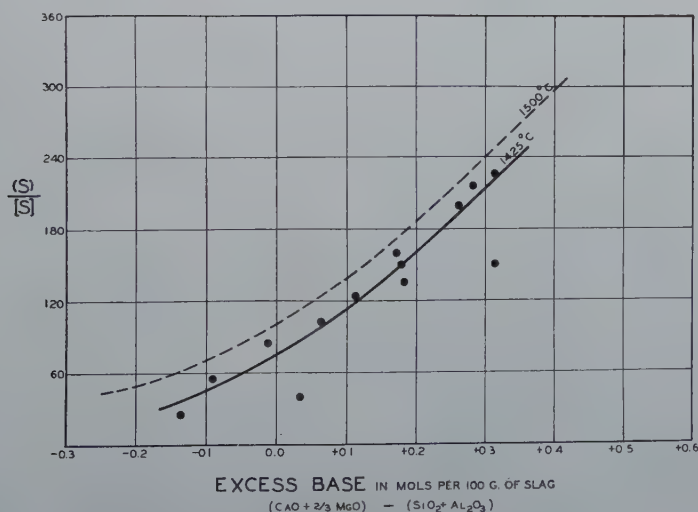

FIG 9—Effect of temperature on desulphurization.

the abscissa (Fig 4).

In order to improve the correlation between the desulphurization ratio and excess base, it was assumed that 1 mol of magnesia was equivalent to only $\frac{2}{3}$ of a mol of lime, that is, $1\frac{1}{2}$ mols of magnesia were equal to 1 mol of base, and the other assumptions were considered to remain the same as before. Excess base was then defined as being equal to $(CaO + \frac{2}{3}MgO) - (SiO_2 + Al_2O_3)$. The variation of the sulphur distribution ratio with this expression for excess base is shown in Fig 7. Considering the accuracy of the data this graph represents a very good correlation.

It was expected that the relationships developed for the 1.5 pct sulphur slags would correlate the data for all the slags at 1500°C irrespective of their sulphur content. However, in the plot of $\frac{(S)}{[S]}$ versus $\frac{CaO + \frac{2}{3} MgO}{SiO_2 + Al_2O_3}$ for slags containing 1.5, 2.5, and 5.0 pct sulphur three curves were obtained as shown in Fig 8. This was also true for the plot of $\frac{(S)}{[S]}$ versus excess base, Fig 7. These curves indicate that an increase in the sulphur concentration of the slag does not result in a proportional increase in the sulphur content of the metal, within the range of slag compositions studied. This phenomenon cannot be readily explained with the present data.

EFFECT OF TEMPERATURE ON DESULPHURIZATION

Fig 9 shows the effect on the desulphurization ratio of decreasing the temperature from 1500 to 1425°C. Because magnesia was shown to be two-thirds the equivalent of lime on a molar basis, it is approximately equivalent to lime on a weight per cent basis. Thus from the two curves in Fig 9 it was possible to plot on a ternary diagram iso-sulphur lines at 1500°C and 1425°C, the coordinates being weight per cent MgO + CaO, SiO_2, and Al_2O_3, as shown in Fig 10. This diagram summarizes the effect of slag composition and temperature on the equilibrium sulphur concentrations in liquid pig iron. Although the sulphur concentrations plotted in Fig 10 were obtained for slags containing 1.5 pct sulphur, on the basis of the observations made with slags of higher sulphur content, these concentrations can be regarded as apply-
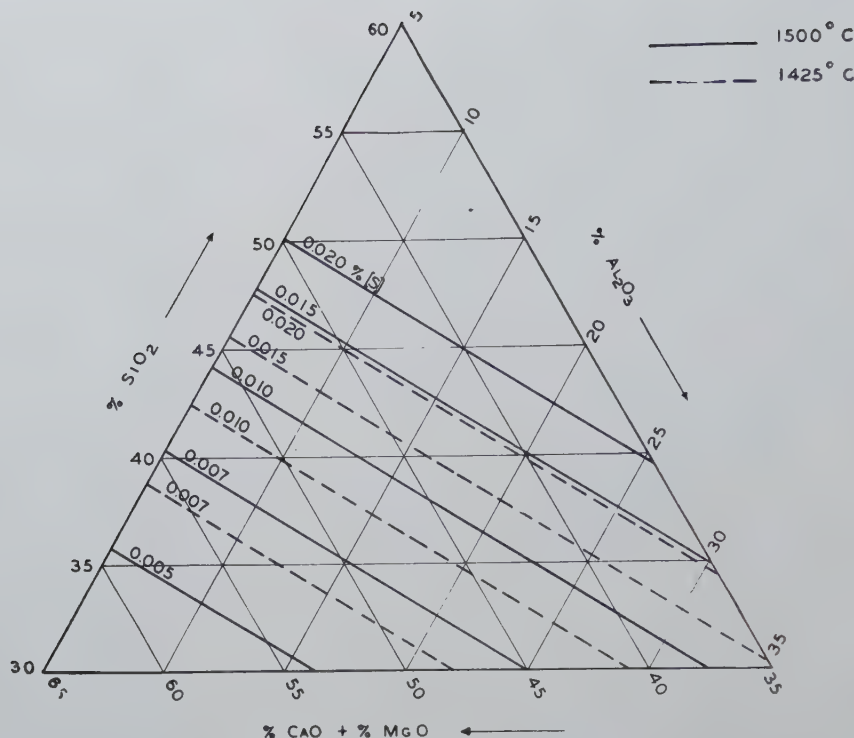
FIG 10—Metal iso-sulphur lines for 1.5 pct sulphur slags at 1500°C and 1425°C. (Slag composition in weight per cent.)

ing to slags analyzing 1.25–2.00 pct sulphur.

Discussion of Results

Although the basicity ratio

$$\frac{CaO + \tfrac{2}{3}MgO}{SiO_2 + Al_2O_3}$$

correlated the data for the 1.5 pct slags, the expression developed for excess base, $(CaO + \tfrac{2}{3}MgO) - (SiO_2 + Al_2O_3)$ in mols per 100 g of slag, is considered to offer a better means of interpreting the results, as it provides a more direct measure of the effective concentrations of the basic constituents present in the slags. Some of the acid slags contained excess acid according to this expression, but this does not necessarily mean that there is "free" acid present, but rather that alumina, because of its amphoteric nature probably acts partly as a base and only partly as an acid. The tendency of alumina to behave as a base is well demonstrated in Fig 7 by the marked decrease in the slope of the curve in the region representing the more acid slags. With alumina considered as acting partly as a base, a

recalculated value for excess base would increase the slope of the curve in this region. From these observations it can be concluded that alumina acts like silica, on a molar basis, in reducing the desulphurizing power of a basic slag; in the more acid slags it is less harmful than silica.

It was observed that three of the very basic slags (47 to 50 pct lime) disintegrated into a fine powder on solidification. This behavior is a well known characteristic of calcium ortho-silicate. Thus it appears that these basic slags contain appreciable quantities of calcium orthosilicate, and therefore, that more than 1 mol of lime has been used to neutralize 1 mol of silica. If this is true, the basic slags contain smaller quantities of excess base than described by the expression $(CaO + \tfrac{2}{3}MgO) - (SiO_2 + Al_2O_3)$.

Thus with alumina acting partly as a base in the more acid slags and with the basic slags containing appreciable quantities of calcium orthosilicate a true graph of the desulphurization ratio versus excess base would have a much steeper slope than occurs with the present expression for excess base.
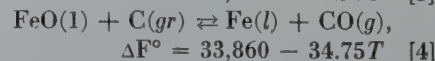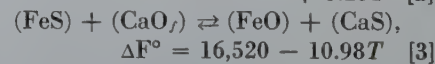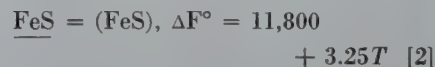
If sulphur is present in blast furnace

slags mainly in the form of calcium sulphide, then desulphurization can be described by the following reaction:
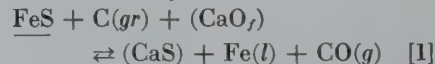
$$\underline{FeS} + C(gr) + (CaO_f)$$
$$\rightleftarrows (CaS) + Fe(l) + CO(g) \quad [1]$$
$$K_1 = \frac{a_{CaS} \cdot a_{Fe} \cdot p_{CO}}{a_{FeS} \cdot a_C \cdot a_{CaO_f}}$$

(CaO_f) represents the free or uncombined lime in the slag. An approximate value for the equilibrium constant K_1 at 1500°F can be calculated from the reactions:

$$\underline{FeS} = (FeS), \ \Delta F° = 11,800$$
$$+ 3.25T \quad [2]$$
$$(FeS) + (CaO_f) \rightleftarrows (FeO) + (CaS),$$
$$\Delta F° = 16,520 - 10.98T \quad [3]$$
$$FeO(1) + C(gr) \rightleftarrows Fe(l) + CO(g),$$
$$\Delta F° = 33,860 - 34.75T \quad [4]$$

Eq 2 was derived from the work of Bardenheuer and Geller[2] on the distribution of sulphur between liquid iron and iron oxide slag. The expression for the standard free energy of reaction [3] as a function of temperature was developed from the calculations made by Darken and Larsen[19] on Bardenheuer and Geller's data for sulphur equilibria between lime-iron oxide slags and liquid iron. Eq 4 was obtained from Chipman's[21] tabulations of the

free energy of formation of liquid iron oxide and carbon monoxide at steelmaking temperatures.

Addition of Eq 2, 3, and 4 results in

$\underline{FeS} + (CaO_f) + C(gr)$

$\rightleftarrows Fe(l) + (CaS) + CO(g)$, $\Delta F°$
$= 38,580 - 42.48T$ [5]
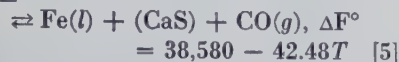
therefore,

$K_1 = 3.39 \times 10^4$ at 1500°C

Since the reaction is endothermic, the equilibrium transfer of sulphur to the slag increases with an increase in temperature, as observed in the experiments.

Under the conditions set up for the experimental work the activity of both the carbon dissolved in the iron and the carbon monoxide gas was equal to unity, the standard states for these two substances being graphite and 1 atm pressure, respectively. The activity of liquid iron was also constant at approximately 0.55 at 1500°C, as determined from Chipman's[18] thermodynamic calculations on the iron-silicon-carbon system. Assuming that activity is proportional to mol fraction for calcium sulphide, iron sulphide and lime, as was done in the determination of the constant K_1 and where Ns and Nm are the number of mols per 100 g of slag and metal, respectively, Eq 1 is transformed to

$K_1 = 3.39 \times 10^4 = 0.55$

$\times \dfrac{(\text{mols CaS}) \times Ns \times Nm}{Ns \times \text{mols [FeS]} \times (\text{mols CaO}_f)}$

$= 0.55 \times \dfrac{(\% \text{ S}) \times Nm}{[\% \text{ S}] \times (\text{CaO}_f)}$

but since Nm is essentially constant and equal to 2.1, then at 1500°C

$2.94 \times 10^4 = \dfrac{(\% \text{ S})}{[\% \text{ S}]} \times \dfrac{1}{(\text{CaO}_f)}$ [6]

According to Eq 6 the desulphurization ratio $\dfrac{(S)}{[S]}$, is proportional to the number of mols of free lime per 100 g of slag. This is in agreement with what was observed when $\dfrac{(S)}{[S]}$ was plotted against mols of excess base for a given sulphur concentration in the slags. However, the slope of the curve $\dfrac{(S)}{[S]}$ versus excess base for the 1.5 pct sulphur slags at 1500°C was only equal to 560, compared with 2.9×10^4 for the slope of the curve $\dfrac{(S)}{[S]}$ versus free lime, as given by Eq 6. Thus the large value calculated for K_1 provides further evidence that the expression $(CaO + \frac{2}{3}MgO) - (Al_2O_3 + SiO_2)$ does not give a true value for the excess base, the actual excess being somewhat smaller.

Previously, in discussing the relationship between desulphurization and slag composition, it has been assumed that molten slags are composed of molecular compounds and their constituent oxides. However, the expression of slag composition in terms of excess base can be used equally well whether slags are composed of ions or of molecules. In the ionization theory the basic oxides produce oxygen ions which are absorbed by silica and alumina to form complex ions of the form $(Si_2O_7)^{-6}$, $(SiO_4)^{-4}$, $(Al_2O_5)^{-4}$. As the basic oxides replace the acid oxides the oxygen ion concentration increases.

The conclusions previously reached regarding the amphoteric properties of alumina in blast furnace slags can be stated in terms of the ionization theory by the following series of steps representing the transition from acidic to basic solutions, each step requiring the addition of oxide ions:

$2Al^{3+} \rightarrow 2AlO^+ \rightarrow Al_2O_3 \rightarrow 2AlO_2^-$
$\rightarrow Al_2O_5^{4-} \rightarrow 2AlO_3^{3-}$
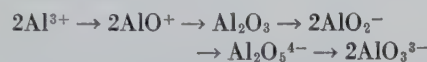
The presence of calcium orthosilicate in the basic slags is shown by the formation of the stable orthosilicate ion SiO_4^{4-} from the metasilicate ion in a similar series.

$2SiO_2 \rightarrow 2SiO_3^{--} \rightarrow Si_2O_7^{6-} \rightarrow 2SiO_4^{4-}$

The concept of ionization also explains the fact that 1 mol of magnesia was not found to be equivalent to 1 mol of lime. The binding forces between magnesium and oxygen ions are greater than those between calcium and oxygen ions.[20] Hence the substitution of 1 mol of magnesia for 1 mol of lime in a slag would result in a decrease in the oxygen ion concentration of the slag. This means that magnesia is not as active a base as lime, and therefore, not equivalent to lime on a molar basis.

Thus, either the molecular or the ionic theories can be employed in explaining the behavior of the various slag constituents. However, blast furnace slags involve such complicated chemical systems that fundamental knowledge is as yet inadequate for the quantitative determination of their properties in the molten state, and therefore it is impossible at present to determine the true value for excess base. This does not mean that the expression $(CaO + \frac{2}{3}MgO) - (SiO_2 + Al_2O_3)$ has no real significance. The equilibrium desulphurization ratios for slags containing about 1.5 pct sulphur have been well correlated with this expression for excess base. The result

is shown in the ternary diagram (Fig 10), which allows the equilibrium values of sulphur in the metal to be determined for blast furnace slags at 1500°C and 1425°C.

Since none of the slags studied contained any manganese oxide, it would be of considerable interest to study under equilibrium conditions the effect on desulphurization of manganese oxide in the slag. Also, in order to better understand the constitution of molten slags, activity measurements should be made of simple binary slag systems. These studies can be made by means of either reversible electromotive force measurements, as described by Chang and Derge[22] or by slag-metal equilibrium investigations.

PRACTICAL CONSIDERATIONS

The present investigation has shown that the equilibrium sulphur concentrations in the metal are considerably lower than those found in practice. Hence, the problem of attaining better desulphurization with blast furnace slags is controlled by the kinetics and not by the thermodynamics of the metal-to-slag transfer of sulphur. It is important that investigations be carried out to determine the mechanism by which desulphurization takes place, in the manner initiated by Chang and Goldman.[23] Of more immediate significance to blast furnace operators would be a study of the desulphurization attained by various methods of mixing slag and metal. It should not be concluded that such an investigation is not warranted because the time required to reach equilibrium was so great in the present study. A simple process of pouring the metal through the slag might well show that considerable quantities of sulphur can be removed by taking advantage of the inherently strong desulphurizing powers of commercial slags without resorting to other desulphurizing agents.

Summary

From the 57 runs made in the experimental furnace covering a range of slag compositions, consisting of 30 to 50 pct lime, 29 to 40 pct silica, 1 to 19 pct magnesia and 6 to 27 pct alumina at 1500°C and 1425°C, the following conclusions have been reached:

1. The sulphur concentrations in pig iron at equilibrium with blast furnace slags are considerably lower than those found in practice.

2. The desulphurization ratio, $\frac{(S)}{[S]}$, for slags containing approximately 1.5 pct sulphur is controlled by excess base, where excess base is equal to $(CaO + \frac{2}{3}MgO) - (SiO_2 + Al_2O_3)$ in mols per 100 g of slag.

3. The effect of lowering the temperature from 1500°C to 1425°C is to increase the equilibrium sulphur concentration in the metal. This increase amounted to 0.001 to 0.004 pct in metal containing 0.005 to 0.020 pct sulphur.

4. Magnesia is only two-thirds the equivalent of lime as a desulphurizing agent on a molar basis, or approximately equal on a weight basis.

5. Alumina acts like silica in reducing the desulphurizing power of a basic slag; in the more acid slags it is less harmful than silica.

6. The sulphur concentration in the metal is not directly proportional to the sulphur in the slag.

Acknowledgments

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Determining density by Archimedes method (Ercker, 1574).

The man in the foreground is weighing a sample in water against an adjustable mixture of gold and silver granules. In the background are the cupelling furnace and accessories and the large matrass for parting gold and silver with nitric acid. (Courtesy Cyril S. Smith.)

The Beryllium-iron System*

○ ○

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Introduction

THERE is considerable interest in beryllium because of its low density (1.84 g per cu cm), high modulus of elasticity (40×10^6 psi), high melting point (1280°C), and special nuclear characteristics. Moreover, it has fair resistance to corrosion and oxidation. However, the purest beryllium known to the authors is relatively brittle at room temperature, and cannot be fabricated readily. The search for improved properties leads naturally to investigations of beryllium alloys and the phase relationships upon which they are based.

The present paper is concerned with the alloys of beryllium and iron, primarily from the standpoint of the equilibrium diagram. Iron was selected (1) because of its all-round importance in metallurgy, and (2) because the beryllium-iron system is known to be quite complex.

The most recent diagram in the literature is that of Gaev and Sokolov,[1] and covers only the iron-rich end up to 16 wt pct beryllium. Beryllium markedly restricts the austenitic field, closing the gamma loop at about 0.4 wt pct (3 at. pct). On the other hand, beryllium is soluble in α-ferrite up to a maximum of 7.5 wt pct (34 at. pct) at the eutectic temperature of 1160°C. The eutectic composition lies at 10 wt pct beryllium (42 at. pct) and corresponds to a mixture of α and FeBe₂ (called β in the present paper). The solid solubility of beryllium in the α phase decreases with decreasing temperature, and makes precipitation-hardening possible. These findings substantiate the earlier work of Oesterheld,[2] Wever and Mueller[3] and Laissus.[4]

In addition to the FeBe₂ (β) mentioned above, Misch[5] has reported on

Table 1 . . . Analyses of Raw Materials

Element	Beryllium		Iron		
	Chemical Analysis		Chemical Analysis Wt Pct	Spectrographic Analysis Wt Pct	Vacuum Fusion Analysis Wt Pct
	Wt Pct	At. Pct			
Silicon	0.034	0.011		0.010	
Aluminum	0.12	0.040		Slight trace	
Molybdenum				0.0007	
Iron	0.10	0.016			
Copper				0.0006	
Magnesium	0.005	0.002			
Tin				0.0001	
Nickel				Trace	
Titanium				0.00005	
Vanadium				Trace	
Chromium				Trace	
Manganese				Trace	
Tantalum				Not found	
Columbium				Not found	
Tungsten				Not found	
Carbon	0.02	0.02	0.006		
Nitrogen	0.015	0.010	0.0007		
Oxygen					0.0005
Hydrogen					0.0267–0.0359
Beryllium Assay	99.4				0.00005

FeBe₅, and indicated evidence for another compound containing still more beryllium.

A preliminary diagram by Gordon,[6] not hitherto published, is given in Fig 1. Besides the phases previously named, there are shown a solid solution of extended range (ε), a compound of limited solubility (ζ), and a high temperature phase (η). Beryllium is designated as θ. The ε field contains the

compound composition FeBe₅, and the ζ phase undoubtedly corresponds to the beryllium-rich compound found by Misch.[5] The region around the ζ phase was proposed by R. J. Teitel based on Gordon's data. The details of the diagram are self-explanatory. It was the unusual complexity of this system that prompted the authors to undertake the present studies. By the same token, more emphasis was placed on the beryllium-rich than the iron-rich end of the diagram.

Experimental Details

RAW MATERIALS

The beryllium employed in this investigation was one of the purest grades available. Its chemical analysis after vacuum melting is given in Table 1. The metal assayed 99.4 wt pct beryllium.

Vacuum melted electrolytic iron of purity shown in Table 1 was the source of iron.
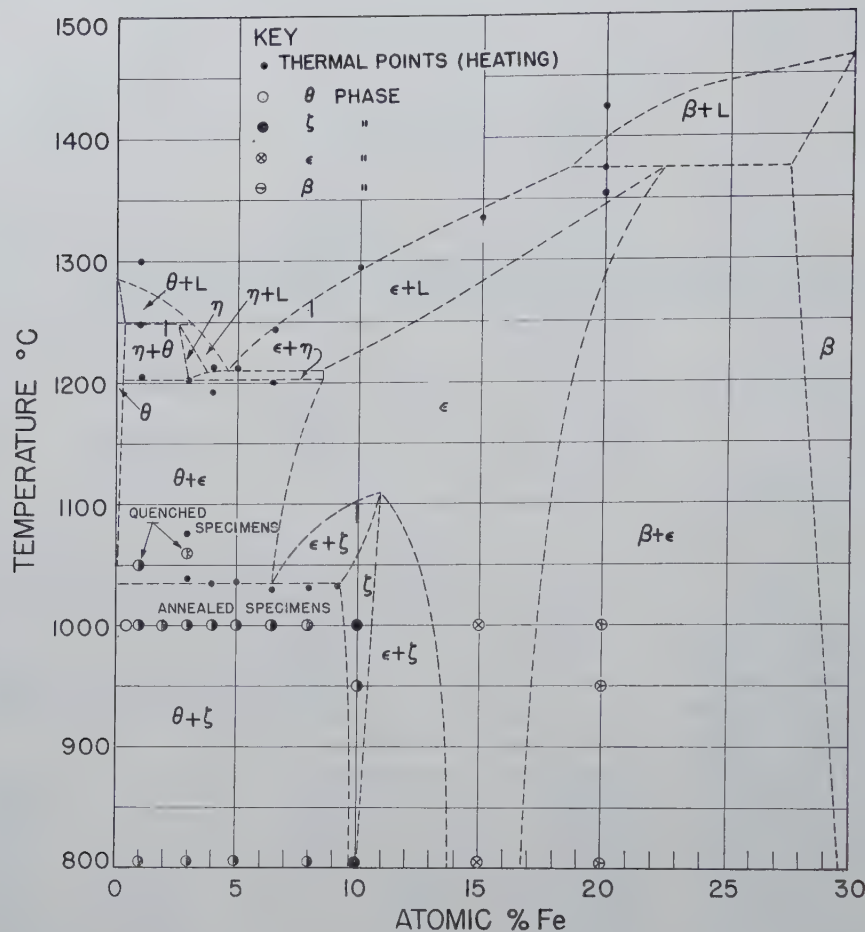
FIG 1—Beryllium-iron system developed by Gordon,[6] based on preliminary studies leading up to the present investigation.

APPARATUS AND PROCEDURE

The alloys were prepared in a vacuum induction furnace, using beryllia crucibles. The resulting ingots were approximately 2 in. high × 1½ in. diam, and weighed 60–150 g depending on composition. The ingots were analyzed top and bottom, and accepted only if the determinations checked within ±0.1 wt pct.

Thermal analysis and solution-quenching experiments were performed in the vacuum furnace shown in Fig 2. It consisted of a molybdenum-wound alundum core, mounted in a water-jacketed steel shell with electrical and vacuum fittings introduced through the sides, thus leaving the top and bottom completely accessible for various interior designs.

The interior arrangement for the thermal analysis runs is shown in Fig 3. The thermocouple was located with respect to the melt by means of a re-entrant tube integral with the bottom of the beryllia crucible. The rate of temperature rise or fall was controlled by varying the furnace volt-

age through an induction regulator driven by a telechron motor. The rates were usually adjusted to 1–2°C per min. Temperatures were recorded automatically for the survey runs, and measured with a K-2 precision potentiometer for the critical determinations. Calibrated platinum-platinum rhodium thermocouples were used for all the critical determinations. It is believed that the accuracy of measurement was within ±10°C above 1350°C, and ±5°C below.

In the solution-quenching experiments, the temperatures were probably accurate to ±2°C. Fig 4 illustrates how this operation was carried out in the vacuum furnace of Fig 2. Small pieces of the alloys to be treated were placed in thin-walled iron capsules for identification and guidance through the furnace. When the solution temperature was believed to approach or exceed the solidus, the iron capsules were lined with beryllia to avoid sticking or iron contamination. The beryllia linings were also employed when powder specimens were treated for X ray measurements. After the furnace

had been evacuated and stabilized at the predetermined temperature, the capsules were pushed into the furnace, one by one, via the charging tube shown at the top right of Fig 4. Each specimen was detained in the heating chamber for the desired time by a molybdenum vane operated from the outside, and then allowed to drop into an externally-cooled silicone oil bath. After all the capsules in the charging tube had been solution-treated and quenched, the bath was disassembled from below, and the samples recovered. Further details on the design and operation of the above equipment are being published elsewhere.

The metallographic techniques used were fairly standard, except for the alloys in the range of 8 to 45 at. pct iron (36 to 84 wt pct). The latter were extremely brittle, and were polished on a Graton semiautomatic unit.* No suitable etchant was found for these compositions. However, they could be examined successfully with polarized

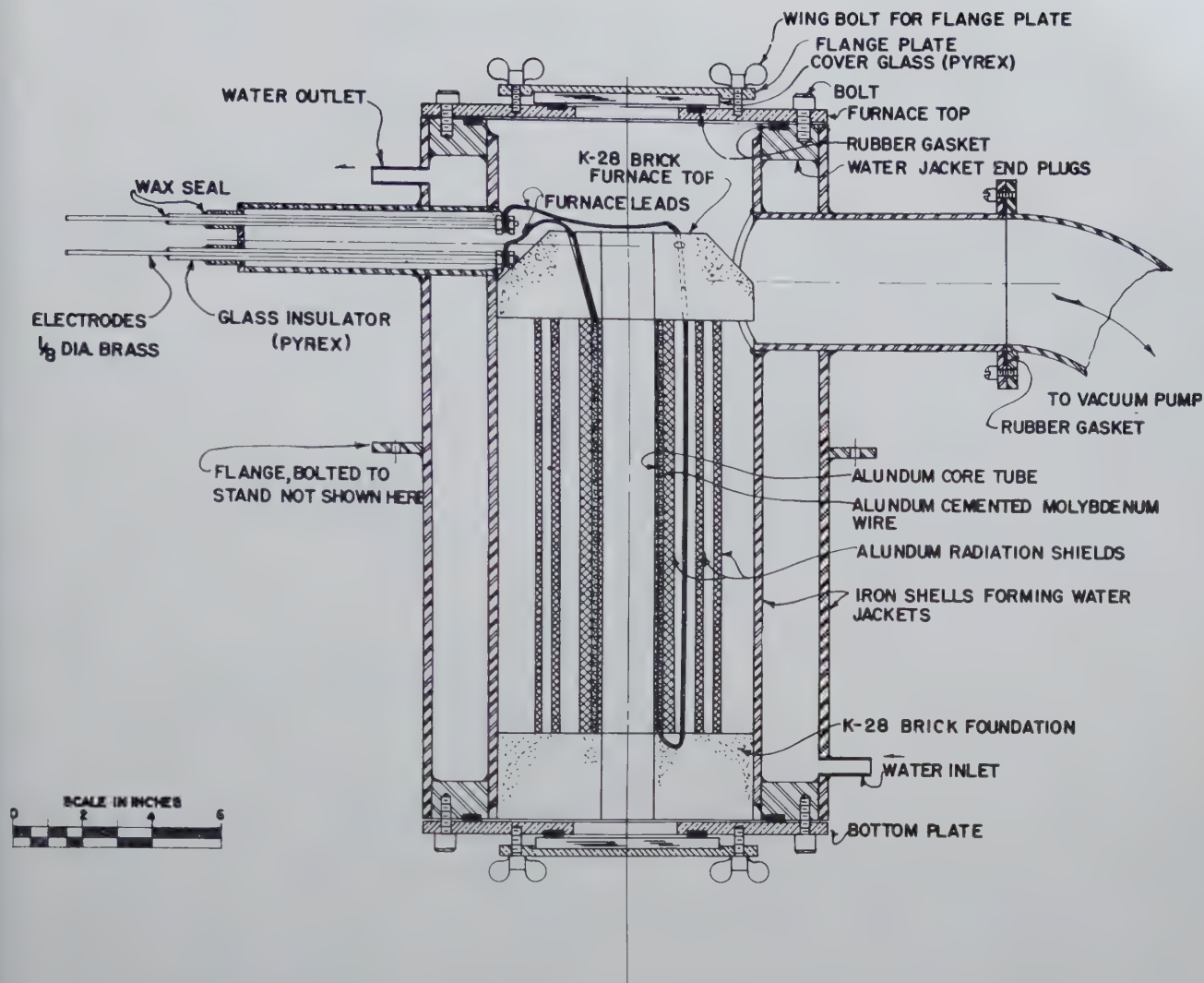* This polishing was done by Mr. Charles Fletcher at Harvard University.

FIG 2—Vacuum furnace used for thermal analysis and solution-quenching experiments. (See Fig 3 and 4.)

light. Alloys containing 0 to 8 at. pct iron were etched with 1 pct HF, while those containing 45–100 at. pct iron were etched with 1 pct nital.

The structures of the phases were studied by standard X ray diffraction procedures using Debye-Scherrer and Phragmen cameras with CoK_α radiation. Most of the solid solubility limits were determined by the lattice-parameter and disappearing-phase methods.

Experimental Results

The individual solid phases are first discussed, starting with beryllium and proceeding in the direction of iron. Following this, the thermal, X ray and metallographic data leading up to the diagram itself are presented in two sections: (1) 0–8 at. pct iron and (2) 8–100 at. pct iron. All compositions are henceforth expressed as atomic percent iron, until at the very end, the
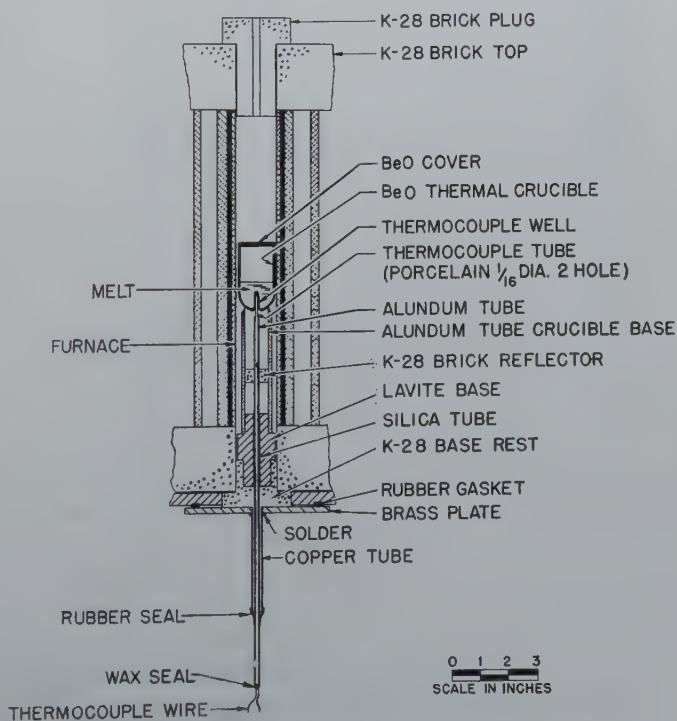
FIG 3—Interior arrangement of vacuum furnace for thermal analysis. (See Fig 2.)
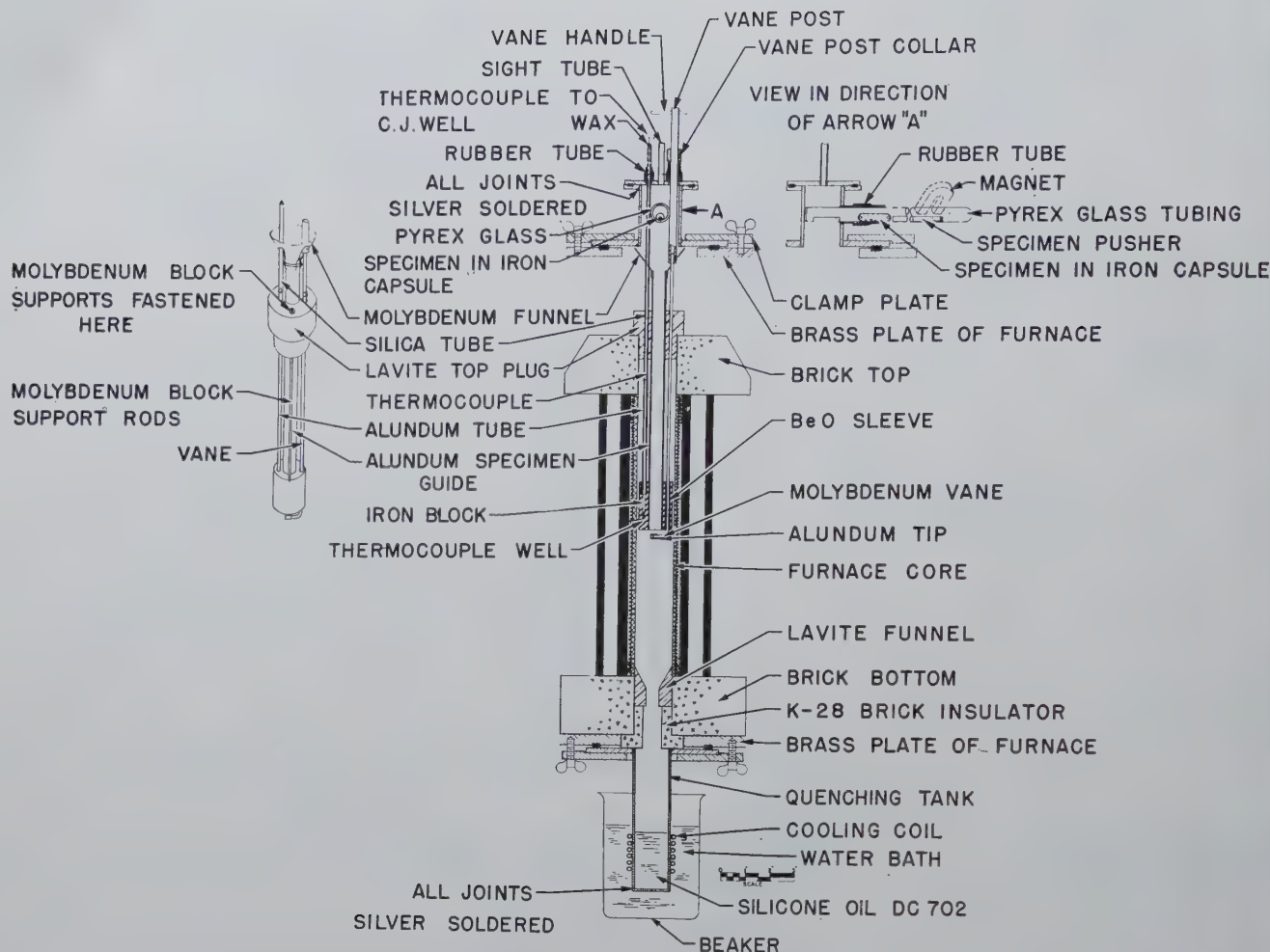
FIG 4—Interior arrangement of vacuum furnace for solution-quenching experiments. (See Fig 2.)

proposed diagram is redrawn with iron at the left and compositions expressed as weight percent beryllium to comply with the convention adopted by the 1948 Metals Handbook. With this arrangement, the phase designations fall into proper sequence.

θ PHASE (Be)

Thermal analysis of the vacuum-melted beryllium stock revealed a double arrest near the melting point, both on cooling and heating (Fig 5). Other sources of beryllium, having different amounts of impurities, also displayed these two heat effects. The upper arrest varied from sample to sample, but the lower one remained quite constant, except when iron was present in excess of 0.1 at. pct. Furthermore, the ratio of the heat liberated (or absorbed) at the two arrests varied from sample to sample. Both Sloman[7] and Losano[8] have likewise observed a double break in the thermal curves for beryllium. Losano[8] reported that the upper arrest is raised to 1284°C with

FIG 5—Inverse-rate thermal curves for vacuum melted beryllium stock.

Table 2 . . . Summary of Phase Structures*

Phase Symbol	Formula	Lattice	Number of Atoms Per Cell	Lattice Dimensions (A.U.)			Density G Per cc (calc)
				a	c	c/a	
θ	Be	H.C.P.	2	2.281	3.577	1.568	1.845
ζ	$FeBe_{11}$	Hex.	18	4.13	10.71	2.59	2.43
ϵ	$FeBe_5$	F.C.C.	24	5.884			3.272
β	$FeBe_2$	H.C.P.	12	4.212	6.853	1.626	4.629
α	Fe	B.C.C.	2	2.861			7.870

* Typical X ray diffraction patterns are shown in Fig 12 and 20.

increasing purity and the lower arrest completely disappears at extremely high purity (99.962 wt pct beryllium). Sloman[7] also attributed the double arrest to impurities, oxygen in particular.

The same conclusion was reached in this work, but the possibility of an allotropic transformation occurring near the melting point was also considered. This alternative was finally judged to be improbable on the following grounds:

1. The heat involved in the lower arrest was too large relative to that of the upper arrest for these phenomena to be regarded as allotropic and melting transformations respectively.

2. Careful study of the temperature-time cooling curves (rather than the inverse-rate curves in Fig 5) indicated that the upper transformation actually took place over a temperature range, while the lower break constituted an isothermal hold. This suggested a binary liquidus and eutectic reaction, and not complete freezing followed by a solid-solid transformation.

3. In addition, when the resulting beryllium-iron diagram was drawn to include the hypothetical allotropic change, it called for completely solid phases in alloys of 0.5 and 1.5 at. pct iron at temperatures of 1190 to 1225°C (refer to Fig 10). However, when these alloys were quenched from this region, they displayed definite evidence of melting.

If the double arrest is caused by an impurity, other than iron, the beryllium-iron alloys under investigation should be considered as ternary rather than binary compositions. It was established that iron was not the active impurity because beryllium samples with as little 0.001 at. pct iron showed a marked double heat effect, very similar to that exhibited by the stock beryllium containing 0.016 at. pct iron. Moreover, all of the experimental findings on the beryllium-iron alloys were consistent with concept that (1) they belonged on a section through a ternary system, and (2) that the "pure" beryllium behaved as if the presence of an impurity caused primary beryllium to crystallize over a range of temperatures down to a binary eutectic temperature where the rest of the beryllium and the impurity-constituent crystallized simultaneously and isothermally.

This is in line with the observations of Sloman[7] who ascribed the eutectic to Be + BeO. However, in the present work, no eutectic configuration could be seen in the microstructure of the beryllium; nor could the BeO phase be identified as such, although there were many inclusions visible (Fig 6). Inasmuch as oxygen analyses were not available for correlation purposes, it appeared preferable to designate the impurity-constituent as X. These relationships will be discussed more fully in the section dealing with 0–8 at. pct iron.

The solid solubility of iron in beryllium was found to be quite limited (less than 0.4 at. pct iron) and no change in lattice parameter could be detected. The lattice constants of beryllium are listed in Table 2, along with data for the other solid phases to be discussed.

ζ PHASE ($FeBe_{11}$)

Misch[5] found diffraction lines from a complex beryllium-rich phase judged to be $FeBe_9$. In the current investigation, a compound was located between 7.8 and 8.2 at. pct iron, which corresponds to the formula $FeBe_{11}$ (or possibly $FeBe_{12}$), rather than $FeBe_9$. All the diffraction lines from this phase can be indexed on the basis of a hexagonal cell of dimensions shown in Table 2. According to the measured density (2.50 g per cc), the number of atoms per unit cell is 18. This is a peculiar result because it implies that there are $1\frac{1}{2}$ formula weights per unit cell. Until a complete solution of the structure by single-crystal analysis is available, the present findings cannot be rationalized.

The range of solubility in the ζ phase is too limited to show a variation of lattice parameter with composition. It transforms on heating via a congruent reaction at 1075°C into the ϵ phase. It is extremely difficult to polish because of brittleness, but when this is properly done, it can be easily identified in the microstructure under polar-

FIG 6—Inclusions in beryllium stock. Larger particles are beryllium carbide; smaller ones are probably a silicon-rich phase. Unetched. Mag. 500 ×.
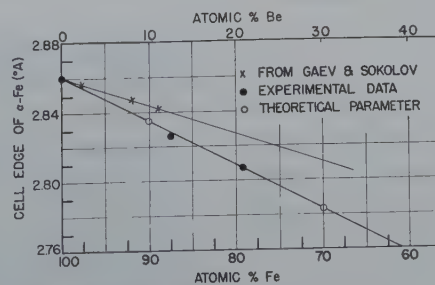

FIG 7—Lattice parameter of F.C.C. ϵ phase as a function of iron content.
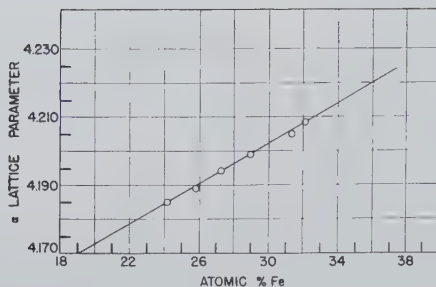
FIG 8—Basal plane parameter of H.C.P. β phase as a function of iron content. c/a ratio does not change measurably over this range.
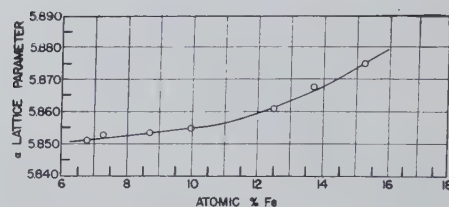

FIG 9—Lattice parameter of B.C.C. iron as a function of beryllium content.
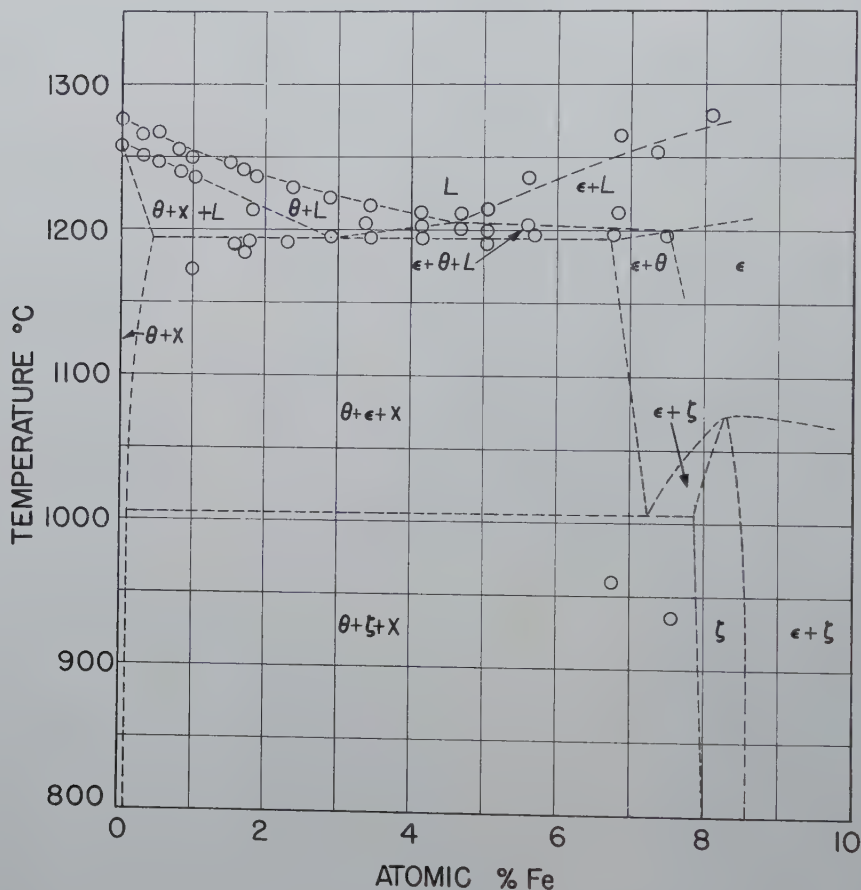

FIG 10—Results of thermal analyses on cooling of 0–8 at. pct iron alloys. Phase fields are drawn to be consistent with X ray results of Fig. 11.

ized light by the feathery appearance illustrated in Fig 21.

ε PHASE (FeBe₅)

Misch[5] determined the structure of this phase to be face-centered cubic and assigned the formula FeBe₅. This was confirmed in the present work (Table 2) except that the phase was found to enjoy a wide range of homogeneity at elevated temperatures (7 to 18 at. pct iron). At lower temperatures,

however, the range becomes narrow (15–17 at. pct iron), but still includes the composition FeBe₅ (16.7 at. pct iron). The variation of lattice parameter with composition, obtained by solution quenching, is given in Fig 7.

Because of its cubic symmetry, ε does not exhibit extinction effects upon rotation under polarized light (Fig 21) and is thereby readily distinguished from ζ on the one hand and β on the other, both of which are optically anisotropic.

β PHASE (FeBe₂)

This compound was first observed by Oesterheld.[2] Later, Misch[5] reported the structure to be hexagonal close-packed of the MgZn₂ type, and this was substantiated here (Table 2).

The β phase was found to extend from 21 to 37.5 at. pct iron, and Fig 8 shows the variation of the basal parameter with iron content. The c/a ratio does not change measurably over this range of composition.

FIG 11—Summary of X ray results on solution-quenched alloys containing 0–8 at. pct iron. Phase fields are drawn to be consistent with thermal data of Fig. 10.
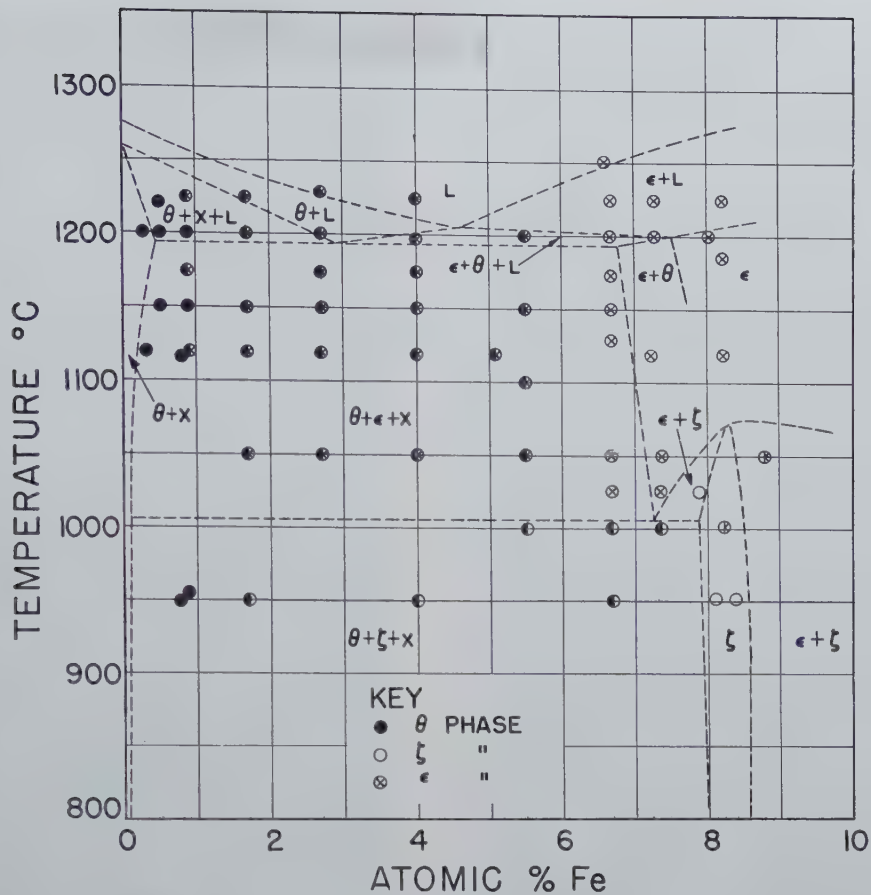
TREATMENT	ANGLE θ FOR Co K_α RADIATION			ATOMIC % Fe	PHASES	WEIGHT % Fe
	0	45	90			
ABOVE 1010°C BELOW 1010°C				0.	θ	0.
BELOW 1010°C				1.0	$\theta + \zeta$	6.0
BELOW 1010°C				3.0	$\theta + \zeta$	15.9
ABOVE 1010°C				4.1	$\theta + \epsilon$	20.9
BELOW 1010°C					$\theta + \zeta$	
ABOVE 1010°C				6.8	$\theta + \epsilon$	31.0
ABOVE 1010°C				8.0	ϵ	35.4
BELOW 1010°C					ζ	

FIG 12—X ray diffraction patterns of alloys containing 0–8 at. pct iron, quenched from above and below 1010°C.

FIG 13 (Above)—1.0 at. pct Fe, as solidified. Large primary grains of θ with ϵ at grain boundaries (degenerate eutectic). Precipitate within the primary grains is also ϵ. Etched with HF. Mag. 100 ×.

FIG 14 (Below)—2.3 at. pct Fe, as solidified. Primary grains of θ surrounded by eutectic. Etched with HF. Mag. 100 ×.

β melts congruently at approximately 1480°C, corresponding to the composition 33 at. pct iron or $FeBe_2$.

Metallographically, β is easily identified because of its polarizing effects. On the beryllium-rich side of the above range, the grains of β are uniformly clear (Fig 22), but at the iron-rich side, a fine lacy structure appears within the grains (Fig 23).

α PHASE (Fe)

Beryllium is appreciably soluble in ferrite, and its effect on the lattice parameter of body-centered cubic iron is given in Fig 9. The present results depart somewhat from those of Gaev and Sokolov,[1] and are in better agreement with the calculated parameter based on atomic radii.

The critical points of pure iron used in the final diagram were taken from the 1948 Metals Handbook as A_3 at
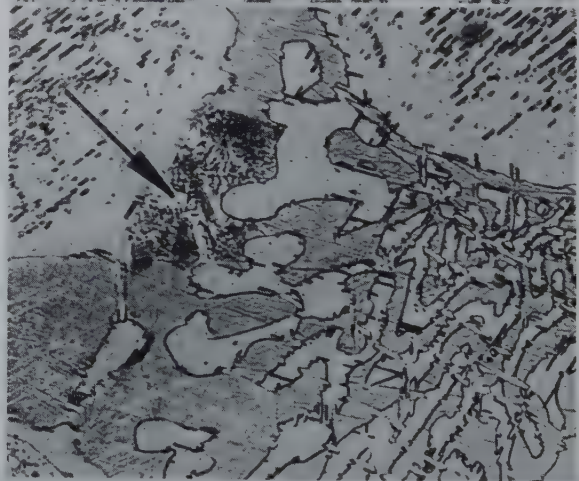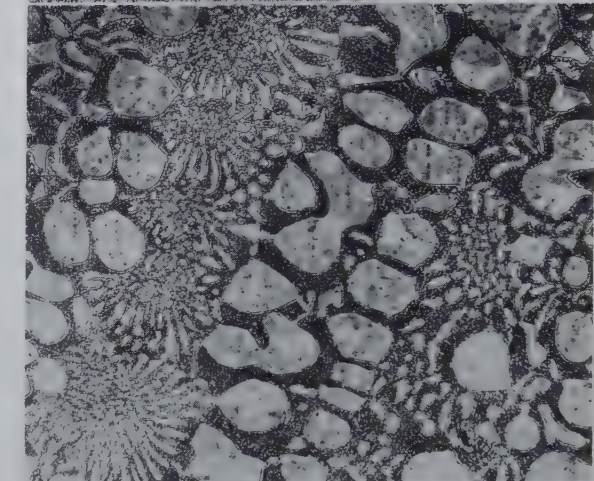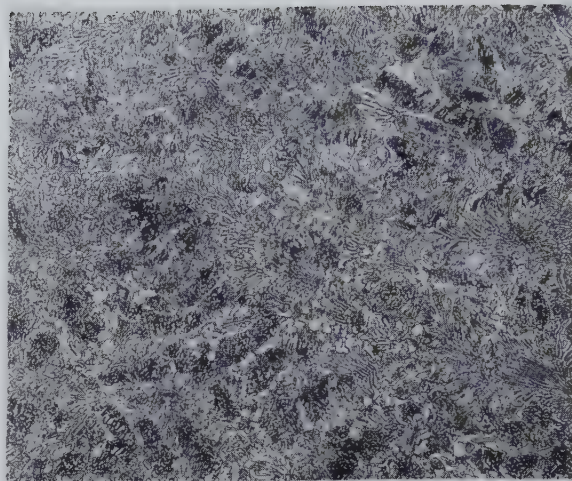
FIG 15 (Above)—4.1 at. pct Fe, as solidified. Mixture of coarse and fine "eutectics." Etched with HF. Mag. 100 ×.

FIG 16 (Center)—5.2 at. pct Fe, as solidified. Primary grains of ϵ with coarse and fine "eutectics." Etched with HF. Mag. 100 ×.

FIG 17 (Below)—1.7 at. pct Fe, as solidified. Primary grains of θ separated by ternary eutectic. Precipitate of ϵ in θ grains. Matrix of eutectic is ϵ, one region of which has undergone eutectoid decomposition to $\theta + \zeta$ (arrow). Other constituents of eutectic are particles of θ and needles of unknown phase polished in relief. Etched with HF. Mag. 1000 ×.
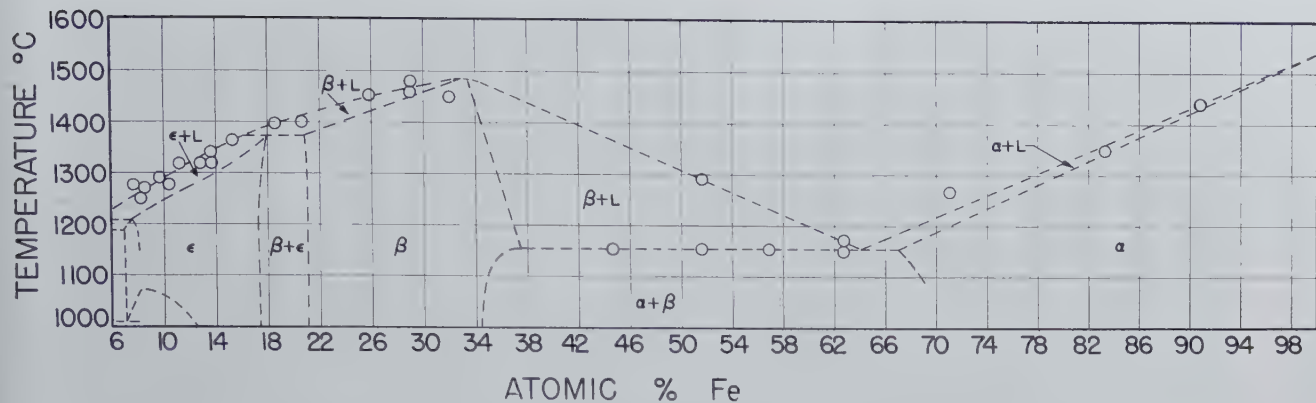
FIG 18—Results of thermal analysis on cooling 8–100 at. pct iron alloys.

KEY

X-RAY SOLUBILITY DETERMINATIONS
- ○ β PHASE
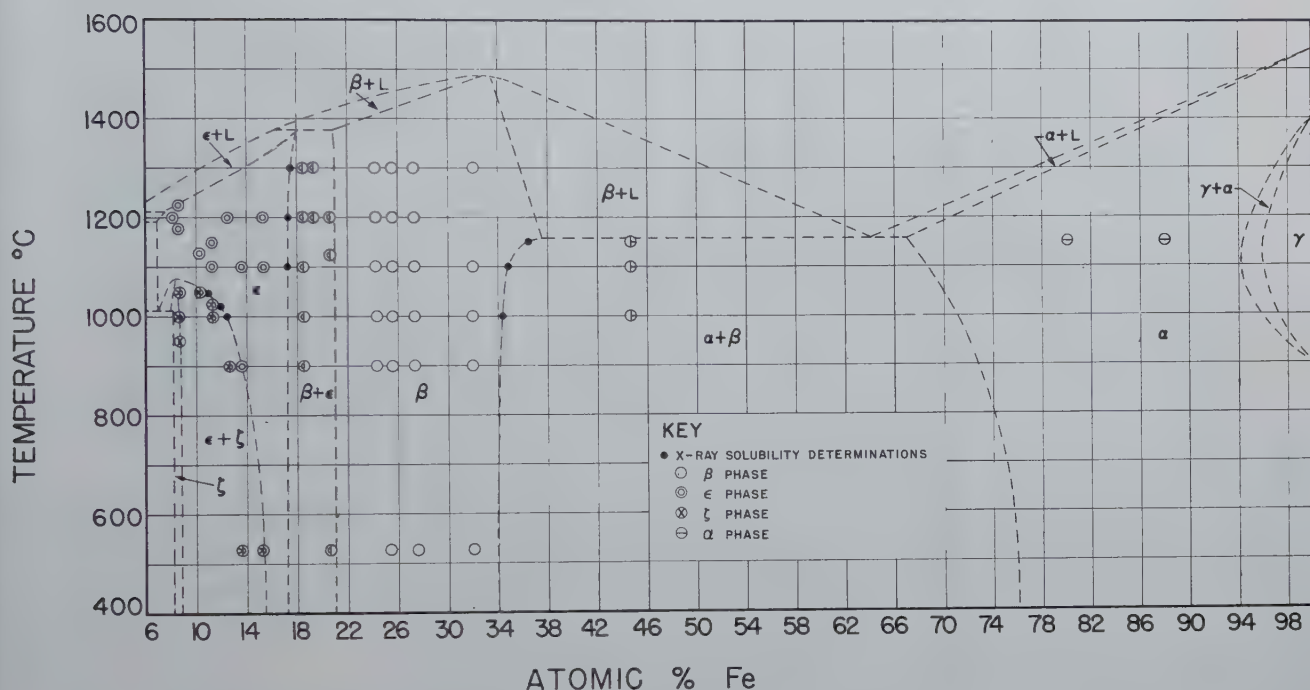- ◎ ε PHASE
- ⊗ ζ PHASE
- ⊖ α PHASE

FIG 19—Summary of X ray results on solution-quenched alloys containing 8–100 at. pct iron.

910°, A_4 at 1400° and m.p. at 1539°C. No studies were made of the austenitic and ferritic phase boundaries. The gamma loop and alpha solubility limits of Gaev and Sokolov[1] were adopted.

0–8 AT. PCT IRON (0–35 WT. PCT)

The results of thermal analyses on cooling of alloys lying in this range are summarized in Fig 10. The liquidus line descends from "pure" beryllium, and reaches a minimum at 4.7 at. pct iron. This occurs at 1210°C, and corresponds to the maximum heat effect in the series. The lower arrest of beryllium descends with increasing iron, and meets the 1190°C isothermal line at about 3.0 at. pct iron, where it yields

the maximum heat effect in this series.

The phase fields outlined in Fig 10 were drawn to be consistent, not only with the thermal points shown, but also with the X ray (Fig 11) and metallographic results of the solution-quenching experiments.*

The latter observations were given more weight in cases where supercooling was suspected to have influenced the thermal arrests. For example, the two points at 950°C in Fig 10 were found to be in error because of supercooling. Hence, the isothermal reaction indicated at 1010°C was ascertained on the basis of the quenching experiments.

---

* Due regard was also given to the phase rule as applied to ternary systems.

Fig 12 offers a comparison of the diffraction patterns of several alloys after quenching from above and below 1010°C.

The transformations corresponding to the various lines in Fig 10 and 11 are deducible from the microstructures. Up to 2.9 at. pct iron, the as-solidified alloys exhibit increasing amounts of an eutectic-like structure, (Fig 13 and 14) which is evidently connected with the 1190° isothermal line. At the same time, the amount of primary θ diminishes. Beyond 3.0 at. pct, a coarse duplex structure appears and reaches a maximum at 4.7 at. pct iron, corresponding to the 1210° intersection. A comparison of the two "eutectics" is found in Fig 15.

FIG 20 table:

TREATMENT	ANGLE θ FOR Co Kα RADIATION			ATOMIC % Fe	PHASES	WEIGHT % Fe
	0	45	90			
ALL BELOW 1000°C				8.0	ζ	35.4
				13.6	$\zeta+\epsilon$	49.2
				15.3	$\zeta+\epsilon$	52.8
				20.5	$\beta+\epsilon$	61.5
				25.5	β	67.9
				32.0	β	74.2
				44.7	$\alpha+\beta$	83.5
				100.	α	100.

FIG 20—X ray diffraction patterns of alloys containing 8–100 pct iron. Annealed below 1000°C.

When the iron is increased above 4.7 at. pct, primary grains of ϵ begin to appear in conjunction with the two "eutectics" (Fig 16). The mottling in the primary ϵ is due to partial decomposition into $\theta + \zeta$ via the eutectoid reaction at 1010°C. In some instances, even the ϵ associated with the "eutectic" structures undergoes such decomposition (Fig 17). However, if the alloys are quenched from above 1010°C, the phase is retained intact. As shown in Fig 13 and 17, some precipitation from the θ phase occurs during slow cooling, in accordance with the sloping solubility limit.

It is believed that the coarser of the two "eutectics" results from the univariant reaction $L \rightarrow \theta + \epsilon$ in the vicinity of 1210°C, and the finer one from the nonvariant reaction $L \rightarrow \theta + \epsilon + X$ at 1190°C (Fig 10). Unfortunately, no evidence was obtained as to the identity of the X constituent. Fig 17 shows primary grains of θ separated by a network of the ternary eutectic. The θ particles and ϵ matrix of the eutectic are clearly distinguishable, but there is also a third phase (polished in relief) in the form of needles that run through the eutectic, causing jagged interfaces between the θ and ϵ. No diffraction lines attribu-

table to this phase were observed.

8–100 AT. PCT IRON (35–100 WT. PCT)

Since the assumed impurity was introduced in proportion to the beryllium content, it was reasonable to expect the ternary behavior of the system to vanish gradually with increasing percentages of iron. Thus, the higher iron range could be treated as a regular binary diagram without undue violation of the phase rule.

The results of thermal analysis for the above composition range are plotted in Fig 18. The liquidus rises to approximately 1480°C at the melting point of the compound FeBe$_2$ (β), then falls to 1165°C (the eutectic of β and α), and finally rises to 1539° at the melting point of pure iron.

The solution-quenching experiments are summarized in Fig 19. Fig 20 illustrates the diffraction patterns of typical alloys in this range.

From the shape of the liquidus lines and extension of the solid phase boundaries, a peritectic reaction was deduced at approximately 1375°C: $L + \beta \rightleftharpoons \epsilon$. No thermal evidence for this reaction was found but the microstructure of an alloy in this range did show signs of β surrounded by ϵ. Furthermore, the

peritectic temperature agrees with that of Gordon's diagram in Fig 1.

The micrographs in Fig 21 to 25 illustrate the types of structures observed. Fig 21 shows a mixture of ζ (light and feathery) and ϵ (dark masses). Fig 22 and 23 are examples of β. Fig 24 typifies the primary β plus eutectic ($\alpha + \beta$) structure, and Fig 25 shows an iron-rich alloy with β precipitated from the α solution matrix.

Final Diagram

The entire diagram is assembled in Fig 26. At the beryllium-end, the ternary behavior is eliminated by collapsing the three-phase regions in an attempt to estimate the nature of the true beryllium-iron binary system. This practice is somewhat arbitrary because there is no information as to the critical temperatures and compositions in the absence of the interfering impurity. However, it is likely that the observed liquidus and solidus temperatures would rise slightly with increasing purity, as found by Losano[8] for beryllium itself.

Fig 26 embodies all these considerations, and is redrawn to conform to the method of presentation adopted by the 1948 Metals Handbook.
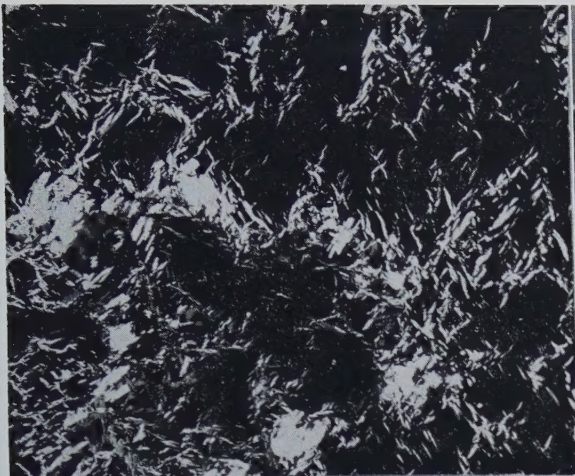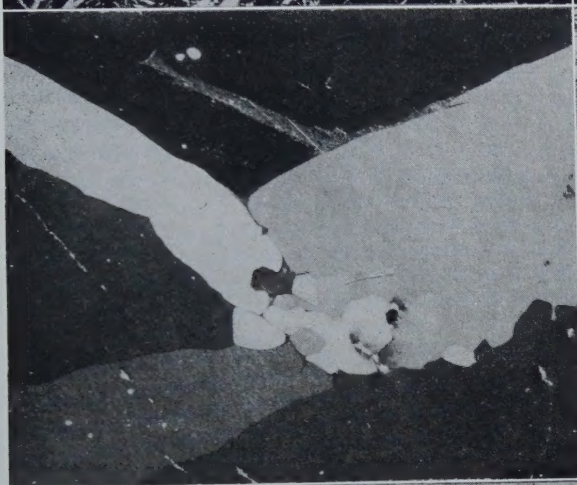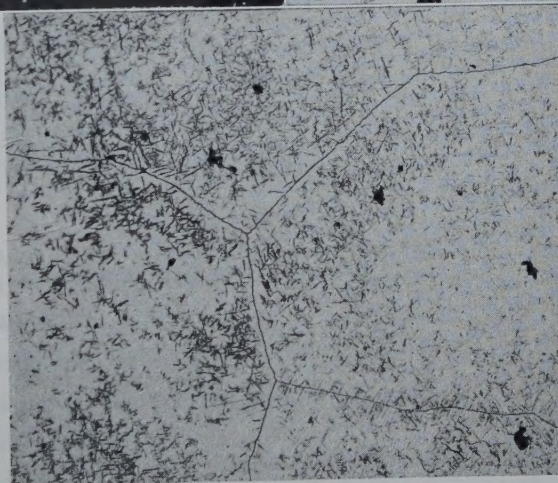
FIG 21—12.5 at. pct Fe, as solidified. ϵ phase is black and massive. ζ phase is light and feathery. Unetched. Illuminated by polarized light. Mag. 100 ×.

FIG 22—27.3 at. pct Fe, as solidified. All β phase. Unetched. Illuminated with polarized light. Mag. 100 ×.

FIG 23—32.0 at. pct Fe, as solidified. All β phase. Note fine pattern within grains. Unetched. Illuminated with polarized light. Mag. 100 ×.

FIG 24—51.2 at. pct Fe, as solidified. Primary grains of β and eutectic of $\alpha + \beta$. Etched with nital. Mag. 100 ×.

FIG 25—70.5 at. pct Fe, as solidified. Primary grains of α with precipitate of β. Etched with nital. Mag. 100 ×.
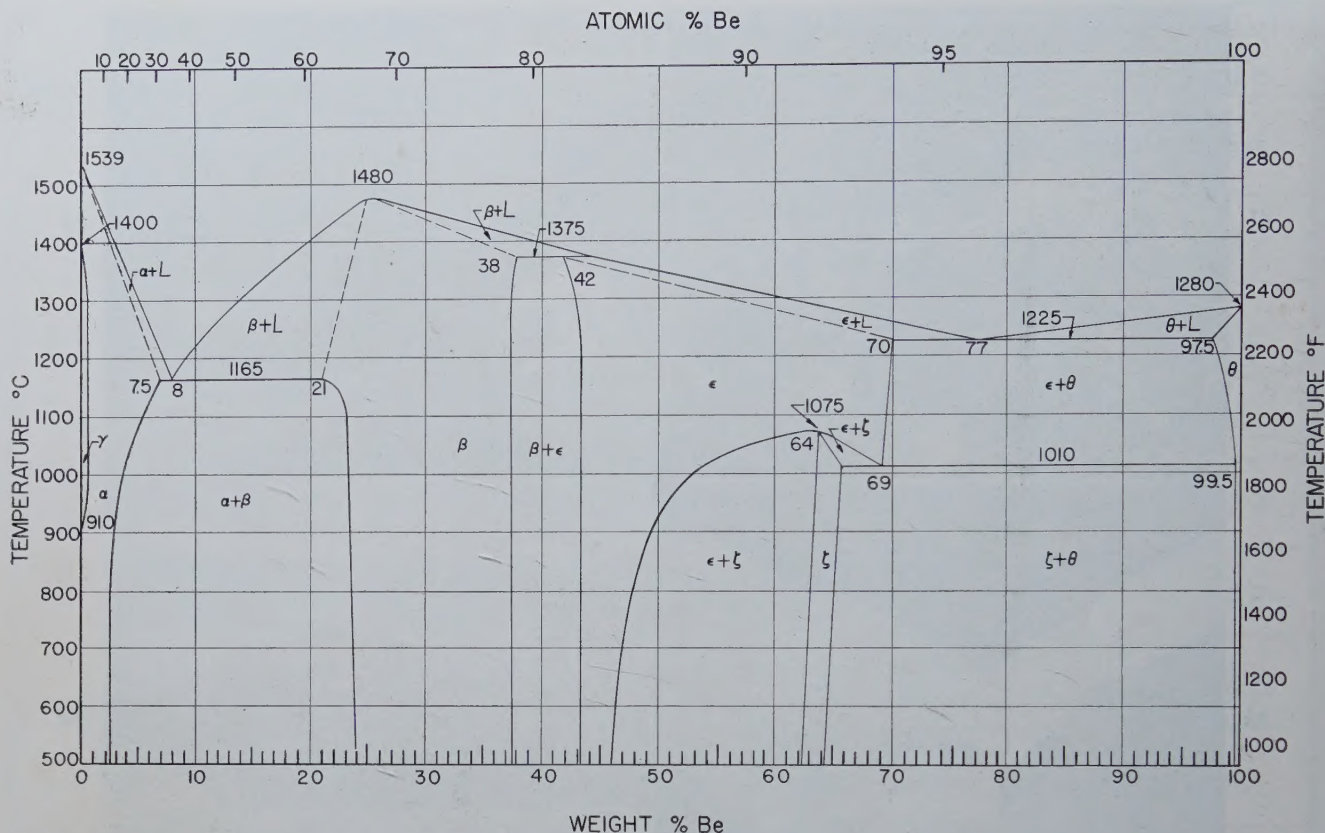
FIG 26—The beryllium-iron system.

Conclusions

1. The available beryllium (99.4 wt pct) was sufficiently impure to exhibit a double arrest at the melting point.

2. Because of the binary nature of this beryllium, the beryllium-iron diagram investigated turned out to be a section through a ternary system. The experimental data were analyzed on this basis, and then the beryllium-iron binary was deduced by allowing the three-component relationships to degenerate into a two-component diagram, thus eliminating one degree of freedom. This approximation was only necessary at the beryllium-end of the system.

3. The solid phases in the system have been identified as listed in Table 2.

4. The beryllium-iron diagram contains two eutectics: one at 1225°C, $L_5 \rightleftarrows \theta_{0.4} + \epsilon_7$; and the other at 1165°C, $L_{64} \rightleftarrows \beta_{37} + \alpha_{67}$. There is also a peritectic at 1375°C, $L_{16} + \beta_{21} \rightleftarrows \epsilon_{18}$; and an eutectoid at 1010°C, $\epsilon_7 \rightleftarrows \theta_{<0.1} + \zeta_8$. The subscripts indicate atomic percent

iron. The corresponding weight percentages are given in Fig 26.

5. The ζ phase decomposes congruently on heating into ϵ at 1075°C, and the β melts congruently at about 1480°C.

6. There are appreciable ranges of solubility in the α, β and ϵ phases, but very limited solubility in the ζ and θ phases.

Acknowledgment

The authors wish to express their appreciation to Mr. Paul Gordon for permission to publish Fig 1 which summarizes his preliminary work leading up to the present investigation; to Dr. A. R. Kaufmann for his criticisms and aid; to Mr. A. B. Bompane who assisted in the thermal analyses; to Miss H. P. Roth for the general metallographic work; to Mr. Charles Fletcher for the special polishing of the brittle alloys; and to Mr. V. M. Mahady for making the beryllia crucibles.

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CORRECTION FEBRUARY ISSUE

"Development of the Modern Zinc Retort in The United States." By H. R. Page and A. E. Lee, Jr. On page 73, column 1, line 3, of February 1949 *Journal of Metals Transactions* the date 1890 should read 1860.

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